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Asphalt Roofing Manufacturers Association

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Richard S. Colyer
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MD-13
U.S. EPA Mail Room
Research Triangle, NC 27711

Via Federal Express:

Dear Mr. Colyer,

The Asphalt Roofing Manufacturers Association (ARMA) is providing the enclosed information in order to assure that you have access to all of the critical data necessary to develop the maximum achievable control technology (MACT) standard for the asphalt roofing manufacturing category. This document is the result of a joint EPA-industry effort to gather data on the industry, its hazardous air pollutant (HAP) emissions and control technologies. Throughout this process, ARMA has been grateful for diligence and cooperation of the staff of the Emission Standards Division of EPA's Office of Air Quality Planning and Standards.

ARMA believes that after reading the attached report and conducting a thorough analysis of the comprehensive emissions testing data, EPA will find that:

- *Emissions are low.* The asphalt roofing industry emits very low amounts of Hazardous Air Pollutants.
- *There are very few major sources.* Very few of the sources in the asphalt roofing category are major sources. Generally, sources are major sources only when they are aggregated with other sources with which they are collocated.
- *MACT for existing blowing stills should be thermal oxidation.* As you know, in selecting the existing source MACT, EPA first identifies the MACT floor (the average emissions achieved by the best-performing 12 percent of sources in that source category) for existing sources and then considers more stringent or "beyond-the-floor" control alternatives. The MACT floor for existing blowing stills is thermal oxidation. No feasible beyond-the-floor alternatives have been identified for blowing stills. Thus MACT for blowing stills should be thermal oxidation.
- *MACT for new blowing stills.* In selecting the MACT for new sources, the MACT floor must equal the level of emissions control currently achieved by the best-controlled similar source. The best-controlled blowing still is controlled by

thermal oxidation, thus MACT for new blowing stills should be thermal oxidation.

- *MACT for existing asphalt roofing lines.* The MACT floor for existing asphalt roofing lines is no control. The potential beyond-the-floor alternative is thermal oxidation. (Other control devices were evaluated but were found to be ineffective for HAP reduction.) Thermal oxidation is not justified for the following technical reasons: it consumes significant energy, produces greenhouse gases and due to low emissions and high costs, is not cost-effective. Moreover, if thermal oxidation were imposed on the very few sources that are major sources, it would impose unfair competitive implications.
- *MACT for new asphalt roofing lines.* The best-controlled asphalt roofing line is controlled by thermal oxidation, thus MACT for new asphalt roofing lines should be thermal oxidation.

These conclusions presented above are substantiated in the accompanying document.

In addition to providing ARMA's analysis of MACT for the asphalt roofing manufacturing category, this document also provides ARMA's comments on the draft report prepared by Eastern Research Group (ERG) dated August 9, 1999 and provided to ARMA on August 19, 2000. That report is titled *Summary of Costing Model Development, Defaults and Assumptions* (hereinafter, "the ERG report") and was prepared under contract to EPA. We are glad to have this opportunity to provide additional information, and in some cases adjustments to the data and assumptions contained in the ERG draft report.

Should you have any questions regarding these comments, please call me at (301) 348-2014 or Angela Jankousky of EME Solutions at (303) 279-7647.

Sincerely,

Russell K. Snyder
Executive Vice President

Enclosures

MACT Analysis for the Asphalt Roofing Manufacturing Category

Prepared for:
Asphalt Roofing Manufacturers Association

Prepared by **EME** Solutions, Inc.
Angela Libby Jankousky

January 15, 2001

Table of Contents

1.0 Introduction – How this Document is Organized

In this document, the Asphalt Roofing Manufacturers Association (ARMA) presents its analysis of the Maximum Achievable Control Technology (MACT) for existing and new asphalt processing sources (or blowing stills) and for existing and new roofing manufacturing lines. ARMA offers this document as a part of its effort to provide substantive input to the United States Environmental Protection Agency (EPA) as it designs a MACT regulation consistent with the requirements of Section 112 (d) of the Clean Air Act. This proposal is the result of a joint EPA-industry effort to gather data on the industry, its hazardous air pollutant (HAP) emissions and control technologies.

This document also provides ARMA's comments on the draft report prepared by Eastern Research Group (ERG) dated August 9, 1999 and provided to ARMA on August 19, 2000. The report is titled *Summary of Costing Model Development, Defaults and Assumptions* (hereinafter, "the ERG report") and was prepared under contract to EPA. The ERG report calculates the cost of installing thermal oxidizers on each of the plants for which ERG had data. ARMA recognizes that the ERG report is in draft and relied on a number of simplifying assumptions. We appreciate this opportunity to provide additional information, and in some cases, suggested adjustments to the assumptions contained in the draft report.

This document is organized as follows:

1. Section 1.0 explains the purpose of this document and its organization.
2. Section 2.0 contains a summary of HAP emissions data for the industry. The ERG report (p. 2) noted that when HAP test data became available, those data could be used to eliminate non-major sources from the MACT cost calculations. This report contains HAP emission estimates for each of the model plants described in the ERG report, and identifies those few types of sources that have the potential to be major sources.
3. Section 3.0 contains new data that supplement the Information Collection Request (ICR) data that ARMA members provided to EPA in 1995 and 1996. These data are used to identify the best-controlled sources for asphalt processing facilities and asphalt roofing manufacturing lines. This information demonstrates that the MACT floor for blowing stills is incineration and the MACT floor for roofing lines is no control.
4. Section 4.0 contains information on control technologies that would be more stringent than (or beyond) the MACT floor, their cost, operating characteristics and efficacy.
5. Section 5.0 contains ARMA's conclusions.

2.0 Additional Data – Roofing Source HAP Emissions

The ERG report (p. 2) noted that when HAP test data became available, those data could be used to eliminate non-major sources from the MACT cost calculations. Those data are now available and were shared with EPA in August of 2000. The data are contained in a spreadsheet (ARMAHAPs.xls) found on the disc enclosed with this document. Most of the data presented were gathered during a sampling program conducted in 1998 and 1999. The EPA's Industrial Studies Branch, Emission Standards Division and ARMA collaborated on the design of the program and it was conducted in accordance with state-of-the-art quality assurance and quality control protocols. This submission supersedes all previous data submissions.

2.1 HAP Emissions Database

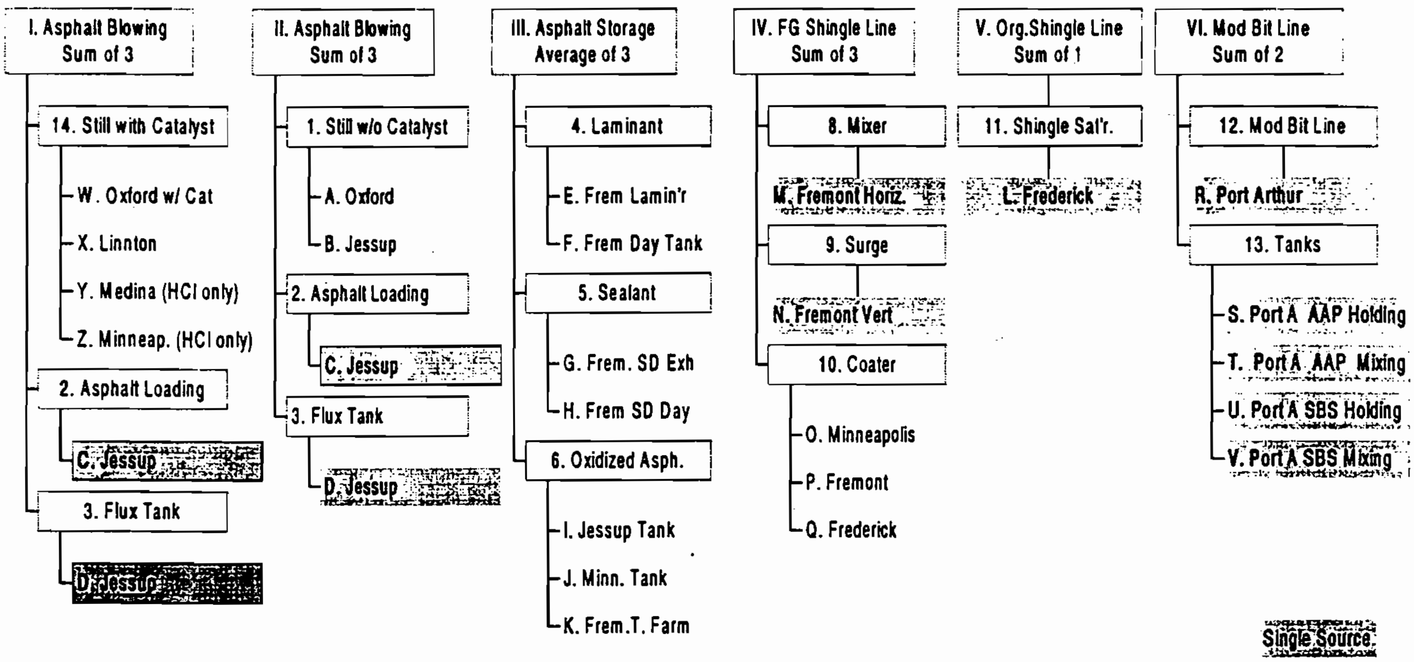
Using the attached spreadsheet (ARMAHAPs.xls), ARMA developed emission factors in tons of HAPs per ton of asphalt throughput for each of six different process units:

I. Asphalt Blowing using a ferric chloride catalyst,
II. Asphalt Blowing without ferric chloride catalyst,
III. Asphalt storage,
IV. A fiber glass line,
V. An organic line, and
VI. A modified bitumen line.

These emission factors can then be multiplied by the line's asphalt throughput in order to calculate total HAP emissions. This section explains the methodology used to develop the emission factors.

The emissions database consists of 14 different types of process equipment, numbered 1 – 14 which are combined to develop the emission factors for the six types of process units (I. – VI.). Twenty-six individual sampling events (labeled A – Z) were conducted to characterize the 14 types of process equipment. During most sampling events, two or three replicates were collected, although there were sometimes as many as five replicates and occasionally only one. Figure 1 shows which individual sampling events A – Z were used to develop each of the process equipment emission factors: 1 – 14. The same nomenclature is used within the ARMAHAPs.xls spreadsheet to label the source types and sampling events.

Figure 1 -- Sources of Emissions Data



2.2 Methodology for the Calculation of Emission Factors

This section explains the methodology used to calculate the emission factors.

2.2.1 Emission Factors for Each Sampling Event: $EF_A \ldots EF_Z$

The emission factor for a sampling event EF_A is calculated from the average of each replicate sample. That is, for each individual HAP, an emission factor (EF_A) is

$$EF_A = \text{Average}\ (EF_i, EF_{ii}, \ldots)$$

Where: EF_i is the emission factor (in tons of the HAP/tons of asphalt used) calculated from a single replicate, i.

EF_A is the emission factor (in tons of the HAP/tons of asphalt used) calculated for the sampling event, A.

Note on Treatment of Values Below the Detection Limit

In cases where a particular HAP was not detected in any of the individual replicates for a single sampling event, the emission factor is determined by assuming the actual emissions were 50% of the detection limit. This is a conservative approach. Even though there are no samples above the detection limit for these values (and the actual values may be zero) they have been set to 50% of their detection limits.

2.2.2 Emission Factors for Each Type of Process Equipment: $EF_1 \ldots EF_{14}$

In most cases, more than one sampling event (A – Z) was conducted in order to determine the emission factor for each particular type of source (1 – 14). In cases where multiple sampling events (A – Z) are available, the emission factors for the sources (1 – 14) were calculated using the following equation:

$$EF_1 = \text{Average}\ (EF_A, EF_B, \ldots)$$

In a few cases, such as source 7, the Saturator, only one source (L. Frederick) was sampled. The single sources are shown in gray on Figure 1. In these cases, the emission factor for the source (EF_7) is determined by multiplying EF_L by a factor of 2 unless the constituent was not detected. Undetected constituents are included at 50% of their detection limits.

$$EF_7 = 2 \text{ x } EF_L$$

In some cases, multiple sources were sampled, but not every constituent was sampled from each source. In cases where only one of the several sources was sampled for a particular HAP, a factor of 2 was also applied in calculating the emission factor for that HAP.

Note on Treatment of Values below the Detection Limit from Multiple Sources

In many cases, HAPs were sampled for, but not detected. If the HAP was sampled for at multiple sources and never detected from that type of source in any of the individual sampling runs, the emissions of that HAP were assumed to be zero for that type of process equipment.

2.2.3 Data Refinements

In July, ARMA transmitted to EPA a spreadsheet containing a summary of HAP emissions testing conducted at roofing plant sources. The current submission refines the data submitted in July. The major differences are described below.

1. The new spreadsheet, explained in Appendix A, contains several workbooks not included in the first spreadsheet, including:
    a. A "Table of Contents",
    b. "Production", a workbook where production rate assumptions for each model line are entered,
    c. "Summary", a workbook that summarizes the HAP emissions for each model line,
    d. "$/ton of HAPs Removed", a workbook that calculates the cost per ton of HAP removed for each of the ERG model plants,
    e. "EFs", a workbook that calculates the HAP emission factors from each model process unit.
2. Data from the Shakopee plant have been removed from the database. Appendix B contains a report from Grant Plummer, Ph.D., of Rho Squared. It explains issues associated with the Shakopee data. The Shakopee data were collected in 1995. This was the first time Fourier Transform Infrared spectroscopy (FTIR) was used at an asphalt source. Since the 1995 sampling, much has been learned about sample conditioning and analyzing complex spectra. The Shakopee results were not consistent with results from similar sources collected later in the sampling program. Because of the inconsistencies, the Shakopee data are not believed to be accurate and were removed from the database for the purpose of calculating emission factors.
3. The only data in the original submission for blowing stills using ferric chloride catalyst came from the Oxford plant. It did not contain values for HCl. The original data have been supplemented by additional comprehensive data from Linnton, and HCl data from Medina and Minneapolis. These data have been peer-reviewed and published. See *"The Magnitude and Source of Air Emissions from Asphalt Blowing Operations"*, Environmental Progress, Spring 1998, David C. Trumbore. This paper is attached as Appendix C.
4. In instances where formaldehyde was sampled using both a species-specific method (such as Method 25A or Method 316) and FTIR (which analyzes for many constituents, and can overreport when the matrix is complex), the FTIR values have been removed.
5. New data collected in April 2000 from Oxford, NC for phenol and toluene have been incorporated. See Appendix D.

2.3 Emission Factors

Table 1 contains the emission factors for each of the sources contained in the ERG report. ERG established these 23 different types of model plants to represent the 63 facilities in the ICR database. As discussed in Section 3.3, ARMA believes there are at least 142 operating lines at more than 104 plants in the United States. In general, the 23 ERG model plants comprise a sample that encompasses the processes and capacities at the 104 actual plants, and can be used to determine whether any of the plants are likely to be major sources. There is one significant exception: none of the model plants is large enough to represent largest of existing asphalt processing plants. Accordingly, ARMA has added one additional model plant. It has a 450,000-ton per year asphalt processing plant (which is larger than any currently operating), a fiber glass line processing 230,000-ton per year of asphalt and a modified bitumen line processing 20,000 ton per year of asphalt. Table 1 is identical to the workbook entitled "EF Summary" in ARMAHAPs.xls. It was generated by multiplying the capacity of the source by the emission factor for the source (from the workbook entitled "EFs" in ARMAHAPs.xls), calculated as described in Section 2.2, above.

Table 1 Tons of HAPs for Various Types of Sources

Model Process Unit	Control Device	Designation	Unit Capacity, Tons of Asphalt per year	Tons of HAPs/Ton of Asphalt Throughput	Tons of HAPs
Asphalt Processing -- No Catalyst	Thermal Oxidizer	A1	50,000	1.10E-02	0.28
		A2	100,000	1.10E-02	0.55
		A3	150,000	1.10E-02	0.83
		A4	200,000	1.10E-02	1.10
		A5	450,000	1.10E-02	2.48
Asphalt Processing -- Catalyst	Thermal Oxidizer	AA1	50,000	2.40E-01	6.00
		AA2	100,000	2.40E-01	12.00
		AA3	150,000	2.40E-01	18.00
		AA4	200,000	2.40E-01	24.00
		AA5	450,000	2.40E-01	54.00
Asphalt Storage	None	B1	50,000	3.74E-03	0.09
		B2	100,000	3.74E-03	0.19
		B3	150,000	3.74E-03	0.28
		B4	200,000	3.74E-03	0.37
		B5	450,000	3.74E-03	0.84
Fiber Glass Substrate Line	None	C1	50,000	6.39E-02	1.60
		C2	100,000	6.39E-02	3.19
		C3	150,000	6.39E-02	4.79
		C4	200,000	6.39E-02	6.39
		C5	230,000	6.39E-02	7.34
Organic Substrate/ multi-product line	None	D1	5,000	4.70E-02	0.12
		D2	15,000	4.70E-02	0.35
		D3	30,000	4.70E-02	0.71
		D4	50,000	4.70E-02	1.18
Modified Bitumen Roofing Line	None	E1	10,000	1.76E-01	0.88
		E2	20,000	1.76E-01	1.76

The values in Table 1 can be used together with ERG's model plants (p. 9) to calculate HAP emissions from each of ERG's model plants. Table 2 shows each model plant's HAP emissions, assuming that the blowing still operates without ferric chloride catalyst.

Table 2 Total Annual HAP Emissions for Model Plants

Model Line Description	ERG Designation	Units Controlled	Asphalt Throughput (tpy)	Predicted HAP Emissions (tons/year)	Statistically Predicted Highest Case HAP Emissions
Asphalt Processing only	A1		**Total:**	**0.37**	**0.55**
		Blowing Still	50,000	0.28	0.29
		Asphalt Storage	50,000	0.09	0.25
	A2		**Total:**	**0.74**	**1.10**
		Blowing Still	100,000	0.55	0.59
		Asphalt Storage	100,000	0.19	0.51
	A3		**Total:**	**1.11**	**1.65**
		Blowing Still	150,000	0.83	0.88
		Asphalt Storage	150,000	0.28	0.76
Oxidized asphalt storage + Fiberglass substrate line	B1/C1		**Total:**	**1.69**	**3.01**
		Asphalt Storage	50,000	0.09	0.25
		FG Line	50,000	1.60	2.76
	B2/C2		**Total:**	**3.38**	**6.03**
		Asphalt Storage	100,000	0.19	0.51
		FG Line	100,000	3.19	5.52
	B4/C4		**Total:**	**6.76**	**12.05**
		Asphalt Storage	200,000	0.37	1.02
		FG Line	200,000	6.39	11.03
Asphalt processing + Fiberglass substrate line	A1/C1		**Total:**	**1.97**	**3.31**
		Blowing Still	50,000	0.28	0.29
		Asphalt Storage	50,000	0.09	0.25
		FG Line	50,000	1.60	2.76
	A2/C2		**Total:**	**3.93**	**6.61**
		Blowing Still	100,000	0.55	0.59
		Asphalt Storage	100,000	0.19	0.51
		FG Line	100,000	3.19	5.52
	A4/C4		**Total:**	**7.86**	**13.23**
		Blowing Still	200,000	1.10	1.18
		Asphalt Storage	200,000	0.37	1.02
		FG Line	200,000	6.39	11.03

Table 2 Total Annual HAP Emissions for Model Plants (Continued)

Model Line Description	ERG Designation	Units Controlled	Asphalt Throughput (tpy)	Predicted HAP Emissions (tons/year)	Statistically Predicted Highest Case HAP Emissions
Oxidized asphalt storage + Fiberglass substrate line + Organic substrate/multi-product line	B1/C1/D1		**Total:**	**1.81**	**3.15**
		Asphalt Storage	50,000	0.09	0.25
		FG Line	50,000	1.60	2.76
		Organic Line	5,000	0.12	0.13
	B4/C1/D1		**Total:**	**2.09**	**3.91**
		Asphalt Storage	200,000	0.37	1.02
		FG Line	50,000	1.60	2.76
		Organic Line	5,000	0.12	0.13
	B4/C2/D2		**Total:**	**3.92**	**6.94**
		Asphalt Storage	200,000	0.37	1.02
		FG Line	100,000	3.19	5.52
		Organic Line	15,000	0.35	0.40
	B4/C3/D3		**Total:**	**5.87**	**10.10**
		Asphalt Storage	200,000	0.37	1.02
		FG Line	150,000	4.79	8.27
		Organic Line	30,000	0.71	0.81
Asphalt processing + Organic substrate/multi-product line	A1/D2		**Total:**	**0.72**	**0.95**
		Blowing Still	50,000	0.28	0.29
		Asphalt Storage	50,000	0.09	0.25
		Organic Line	15,000	0.35	0.40
	A2/D3		**Total:**	**1.44**	**1.90**
		Blowing Still	100,000	0.55	0.59
		Asphalt Storage	100,000	0.19	0.51
		Organic Line	30,000	0.71	0.81
Asphalt processing + Fiberglass substrate line + Organic substrate/multi-product line	A2/C1/D1		**Total:**	**2.45**	**3.99**
		Blowing Still	100,000	0.55	0.59
		Asphalt Storage	100,000	0.19	0.51
		FG Line	50,000	1.60	2.76
		Organic Line	5,000	0.12	0.13
	A3/C3/D3		**Total:**	**6.60**	**10.73**
		Blowing Still	150,000	0.83	0.88
		Asphalt Storage	150,000	0.28	0.76
		FG Line	150,000	4.79	8.27
		Organic Line	30,000	0.71	0.81

Table 2 Total Annual HAP Emissions for Model Plants (Continued)

Model Line Description	ERG Designation	Units Controlled	Asphalt Throughput (tpy)	Predicted HAP Emissions (tons/year)	Statistically Predicted Highest Case HAP Emissions
Asphalt processing + Fiberglass substrate line + Modified Bitumen Roofing Line	A2/C1/E1		**Total:**	3.21	**4.73**
		Blowing Still	100,000	0.55	0.59
		Asphalt Storage	100,000	0.19	0.51
		FG Line	50,000	1.60	2.76
		Mod Bit	10,000	0.88	0.88
	A4/C4/E1		**Total:**	8.74	**14.11**
		Blowing Still	200,000	1.10	1.18
		Asphalt Storage	200,000	0.37	1.02
		FG Line	200,000	6.39	11.03
		Mod Bit	10,000	0.88	0.88
	A5/C5/E2[1]		**Total:**	***12.42***	***19.38***
		Blowing Still	450,000	2.48	2.65
		Asphalt Storage	450,000	0.84	2.29
		FG Line	230,000	7.34	12.69
		Mod Bit	20,000	1.76	1.76
Oxidized asphalt storage + Organic substrate/multi-product line	B1/D1		**Total:**	0.21	**0.39**
		Asphalt Storage	50,000	0.09	0.25
		Organic Line	5,000	0.12	0.13
Oxidized asphalt storage + Fiberglass substrate line + Modified bitumen roofing line	B1/C1/E2		**Total:**	3.45	**4.77**
		Asphalt Storage	50,000	0.09	0.25
		FG Line	50,000	1.60	2.76
		Mod Bit	20,000	1.76	1.76
Modified bitumen roofing line	E1		**Total:**	0.90	**0.93**
		Mod Bit	10,000	0.88	0.88
		Asphalt Storage	10,000	0.02	0.05
			Total:	1.79	**1.86**
	E2	Mod Bit	20,000	1.76	1.76
		Asphalt Storage	20,000	0.04	0.10

As can be seen from Table 2, predicted HAP emissions from all of the model plants are significantly below the 25-ton per year threshold that defines a major source for HAPs. Additional statistical analysis was conducted to determine the confidence interval associated with these values. Two standard deviations were added to the predicted HAP emissions for each plant. These values are labeled "Statistically Predicted Highest Case HAP Emissions" and are shown in the right-hand column. The highest emitting plant is the one ARMA added. (It is designated A5/C5/E2 and has a 450,000-ton per year asphalt

[1] This model plant was developed by ARMA to represent a 450,000-ton per year asphalt processing plant, a 230,000-ton per year fiber glass line and a 20,000 ton per year modified bitumen line. It is the plant with the largest emissions.

processing plant, a 230,000-ton per year fiber glass line and a 20,000 ton per year modified bitumen line). Assuming the data are normally distributed, the emission estimate generated in this way (by adding two standard deviations) will be greater than the actual emissions for 97.5% of plants that would be contained within the data set described by this average and standard deviation. The highest case HAP emissions from this plant are far less than 25 tons per year of HAPs, and no individual HAP exceeds 10 tons per year.

Table 3 shows only those sources that have asphalt blowing stills. The HAP emissions are calculated assuming that the blowing still operates using ferric chloride catalyst on a continuous basis. This is a very conservative assumption.

Table 3 HAP Emissions, with Catalyst

Model Plant Description	ERG Designation	Units Controlled	Asphalt Through put (tpy)	HAP Emissions (tons/year)	Total HCl Emissions	Major Source?
Asphalt Processing only	A1		**Total:**	**6.09**		**No**
		Blowing Still	50,000	6.00	5.83	
		Asphalt Storage	50,000	0.09	0.00	
	A2		**Total:**	**12.19**		**Yes**
		Blowing Still	100,000	12.00	**11.67**	
		Asphalt Storage	100,000	0.19	0.00	
	A3		**Total:**	**18.28**		**Yes**
		Blowing Still	150,000	18.00	**17.50**	
		Asphalt Storage	150,000	0.28	0.00	
Asphalt processing + Fiberglass substrate line	A1/C1		**Total:**	**7.69**		**No**
		Blowing Still	50,000	6.00	5.83	
		Asphalt Storage	50,000	0.09	0.00	
		FG Line	50,000	1.60	0.01	
	A2/C2		**Total:**	**15.38**		**Yes**
		Blowing Still	100,000	12.00	**11.67**	
		Asphalt Storage	100,000	0.19	0.00	
		FG Line	100,000	3.19	0.02	
	A4/C4		**Total:**	**30.76**		**Yes**
		Blowing Still	200,000	24.00	**23.33**	
		Asphalt Storage	200,000	0.37	0.00	
		FG Line	200,000	6.39	0.04	
Asphalt processing + Organic substrate/multi-product line	A1/D2		**Total:**	**6.45**		**No**
		Blowing Still	50,000	6.00	5.83	
		Asphalt Storage	50,000	0.09	0.00	
		Organic Line	15,000	0.35	0.02	
	A2/D3		**Total:**	**12.89**		**Yes**
		Blowing Still	100,000	12.00	**11.67**	
		Asphalt Storage	100,000	0.19	0.00	
		Organic Line	30,000	0.71	0.04	

Table 3 (Continued) HAP Emissions, with Catalyst

Asphalt processing + Fiberglass substrate line + Organic subtrate/multi-product line	A2/C1/D1		**Total:**	**13.90**		**Yes**
		Blowing Still	100,000	12.00	**11.67**	
		Asphalt Storage	100,000	0.19	0.00	
		FG Line	50,000	1.60	0.01	
		Organic Line	5,000	0.12	0.01	
	A3/C3/D3		**Total:**	**23.78**		**Yes**
		Blowing Still	150,000	18.00	**17.50**	
		Asphalt Storage	150,000	0.28	0.00	
		FG Line	150,000	4.79	0.03	
		Organic Line	30,000	0.71	0.04	
Asphalt processing + Fiberglass substrate line + Modified Bitumen Roofing Line	A2/C1/E1		**Total:**	**14.66**		**Yes**
		Blowing Still	100,000	12.00	**11.67**	
		Asphalt Storage	100,000	0.19	0.00	
		FG Line	50,000	1.60	0.01	
		Mod Bit	10,000	0.88	0.00	
	A4/C4/E1		**Total:**	**31.64**		**Yes**
		Blowing Still	200,000	24.00	**23.33**	
		Asphalt Storage	200,000	0.37	0.00	
		FG Line	200,000	6.39	0.04	
		Mod Bit	10,000	0.88	0.00	

As can be seen from Table 3, most of the sources that include ferric chloride catalyzed asphalt processing generate less than 25 tons of potential total HAPs, but would be considered major sources because they have the potential to emit more than 10 tons of HCl annually. As mentioned above, the potential HAP emissions are calculated assuming that the blowing still operates using ferric chloride catalyst on a continuous basis. In reality, sources use ferric chloride only when it is required due to raw material quality characteristics, specific product property requirements, and customer specifications. To ARMA's knowledge, few blowing stills use ferric chloride on a continuous basis.

2.4 Conclusions Regarding HAP Emissions

The data presented here represent a comprehensive investigation of HAP emissions from asphalt processing and the manufacture of asphalt roofing products. In general, the emissions are very low and often less than the limit of detection for the method. A thorough analysis of the data using conservative assumptions indicates that it is extremely unlikely that any roofing plants that do not include ferric chloride catalyzed asphalt processing are major sources of HAP emissions (i.e., major sources under CAA §112).

3.0 Additional Data – Emission Control Technologies

As explained in EPA's publication entitled Taking Toxics Out of the Air (EPA452K00002, August 2000):

"The MACT floor is established differently for existing sources and new sources:

- For **existing sources**, the MACT floor must equal the average emissions limitations currently achieved by the best-performing 12 percent of sources in that source category, if there are 30 or more existing sources. If there are fewer than 30 existing sources, then the MACT floor must equal the average emissions limitation achieved by the best-performing five sources in the category.

- For **new sources**, the MACT floor must equal the level of emissions control currently achieved by the best-controlled similar source."

ARMA offers the information in Sections 3.1 and 3.2 to assist in determining:

1) the average emission limitation achieved by the best performing 12 percent of existing sources, i.e., the MACT floor for existing sources, and
2) the "best-controlled similar source" in order to determine new source MACT.

3.1 Asphalt Plant (Blowing Still) Control Technologies

3.1.1 The MACT Floor for Existing Sources

Based on a review of the ICR data, the ERG report draws the conclusion that all of the blow stills in the industry are controlled by thermal oxidation. ARMA believes this information is correct based on the information available.

3.1.2 New Source MACT Floor

ARMA did poll its members to determine whether any of the blowing stills used additional control technologies to reduce emissions of hydrochloric acid (HCl). Although one company had considered the use of technology to control HCl emissions, no company had such a technology in place in 1995, nor does any company currently have such technology in place. In addition, one member company who was using ferric chloride modeled their actual worst-case HCl emissions and determined there were no ground level impacts. Thus, thermal oxidation is the new source MACT floor, in addition to being the existing source MACT floor.

3.2 Roofing Line Control Technologies

In order to obtain the most complete picture of control technologies in use within the asphalt roofing manufacturing category, ARMA obtained copies of all ICR information originally submitted to EPA and, additionally, asked its members and others within the roofing industry to supplement the data submitted. Some of the additional data are from members who either did not respond to the original ICR or did not respond completely. The remaining additional data are corrections or revisions to the original data. It should be noted that the industry considers the data confidential, and managed it through a consultant operating within rigorous confidentiality constraints. Although the response rate to ARMA's requests was not 100%, significant additional data have been collected and are appended to this report. See Appendix E.

3.2.1 The MACT Floor for Existing Sources

Section 4.1 of the ERG report contains the following statement:

> The devices used to control process equipment emissions in the ICR database include thermal oxidizers and PM control devices. The PM control devices used by the facilities are not expected to reduce gaseous HAP emissions. Consequently, *the assumption was made* that the MACT for all process equipment covered by the asphalt roofing and processing NESHAP will be thermal oxidation, because no control technology has been identified to achieve better reductions of gaseous HAP compounds. (Emphasis added.)

ARMA recognizes that ERG assumed that MACT would be thermal oxidation in order to develop worst-case (high) cost estimates for the asphalt roofing and processing standard (as further explained on page 3 of the ERG report). ARMA offers the following information that demonstrates that the "average emission limitation defined by the best performing 12 percent of existing sources" (i.e., the MACT floor) is no control.

Existing Source Control Technologies

Table 4 contains a summary of the data contained in Appendix B. It shows the control devices used on roofing lines, including those producing organic felts, fiber glass shingles, organic shingles, and modified bitumen products in 1995, the year the ICR was completed.

Table 4 – Emissions Controls on Production Lines[2]

Control Device	Number of Roofing Lines	% of Roofing Lines
Thermal Oxidizer	7	4.9%
Afterburner	7	4.9%
Some type of filtration, scrubbing or mist elimination	80	56.4%
No control	21	14.8%

Thermal Oxidizers

Of the 142 operating roofing lines of which ARMA has knowledge, 7 (or 4.9%) had incineration or thermal oxidation in 1995.

[2] This table contains devices that control the roofing lines themselves in 1995, i.e.: in order to be counted on this list, the control device must be installed so as to control the coater, saturator or modified bitumen coater. In some cases, there are control units associated with ancillary process components such as mixers or asphalt storage tanks. Generally, emissions from these units are minimal, and they are tied into whatever technology is used to control the production emissions. Because of the prevalence of thermal oxidizers at sites with blowing stills, these ancillary sources are more likely to be tied into thermal oxidizers if there is a blowing still on the site.

Afterburners

As can be seen from Table 4, an additional seven roofing lines were equipped with afterburners. Afterburners typically operate at lower temperatures (1250°F or lower) than thermal oxidizers. Subpart UU (Standards of Performance for Asphalt Processing and Asphalt Roofing Manufacture) of PART 60 (Standards Of Performance For New Stationary Sources) of Title 40 of the Code of Federal Regulations contains the following definition of "afterburner": *a exhaust gas incinerator used to control emissions of particulate matter*. In Table 3-1 of the 1972 EPA document entitled *Afterburner Systems Study* (Rolke, 1972, attached as Appendix F), it was noted that 90% destruction of hydrocarbon emissions is obtained from afterburners operating between 1100 – 1250°F, with a residence time of 0.3 – 0.5 seconds. These values are typical of afterburners installed at asphalt roofing manufacturing plants.

As both thermal oxidizers and afterburners operate by oxidizing hydrocarbon emissions, the afterburners were evaluated to determine whether they should be included in the group with thermal oxidizers. As detailed below, these devices do not significantly reduce HAP emissions, and may even increase HAPs as more complex constituents (which may not be HAPs) break down into simpler HAPs (such as formaldehyde).

This phenomenon (increased HAP emissions) was observed at Plant 10. Coater emissions from Plant 10 are controlled by an afterburner (see Table 5). This device operates at 1200°F, with a residence time of 0.5 seconds. The complete emissions testing data are found in Appendix A.

Table 5 – Coater Emissions

Controlled by an Afterburner

	Before Control	After Control	% Removal Efficiency
	(Lb/lb of Asphalt)		
Non HAPs			
THC as Carbon	2.40E-04	1.26E-05	94.75%
Carbon Monoxide	1.01E-04	1.54E-04	-53.11%

HAPs detected			
Formaldehyde	7.97E-07	7.72E-06	-869.16%
Carbonyl Sulfide	9.45E-06	5.31E-06	43.75%
Naphthalene	8.64E-08	7.53E-09	91.28%
2-Methyl naphthalene	1.41E-07	≤6.50 E-08	≥53.98%
Phenanthrene	8.83E-08	≤6.50 E-08	≥26.42%
Fluorene	6.32E-08	≤6.50 E-08	≈0%
2-Methyl phenol	8.14E-08	≤6.50 E-08	≥20.19%
4-Methyl phenol	1.01E-07	≤6.50 E-08	≥35.93%
Overall HAP Emissions			
Total HAPs (tons/year)	1.2	1.5	≈-23.7%

The following HAPs were tested for, but not detected in the emissions from the coater: hydrochloric acid, benzene, phenol, xylene, pyrene, toluene, and 1,3-butadiene.

Due to the increase in formaldehyde emissions, the HAP emissions actually *increased* as a result of the operation of the afterburner.

Figure 2 shows the theoretical relationship between temperature and residence time for a mix of two HAPs (benzene and toluene) that are sometimes found in emissions from asphalt roofing operations. This calculation is based on the equation[3]:

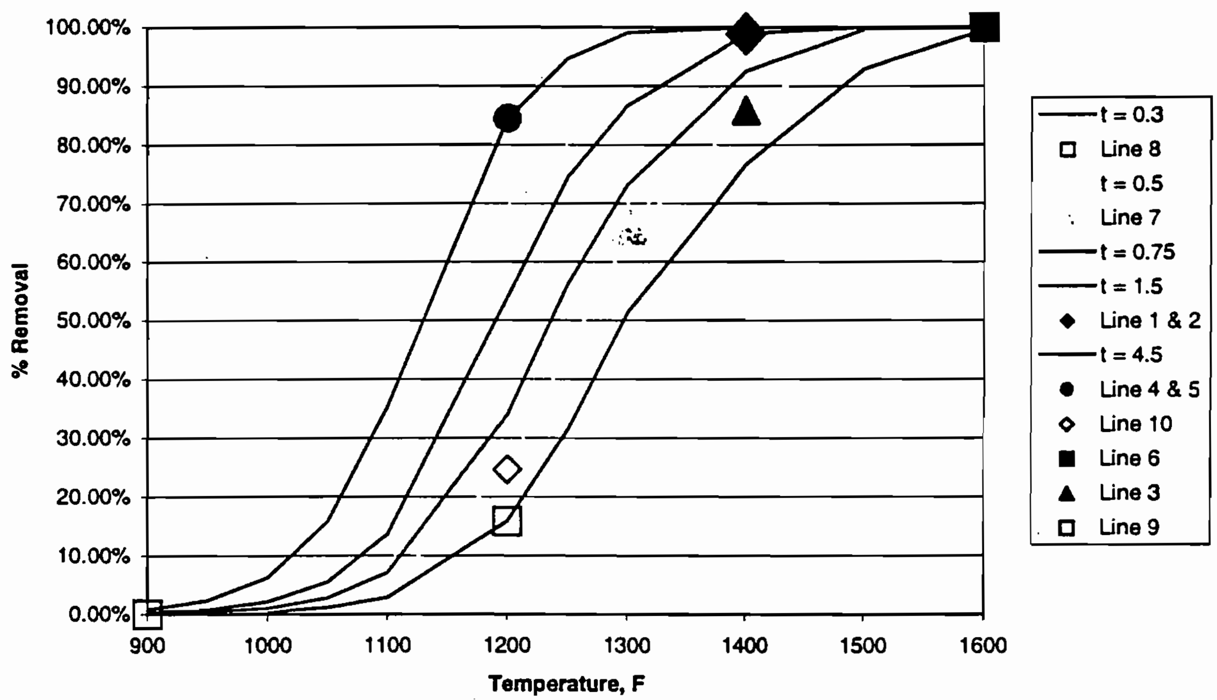
$$D = 1 - e^{-Vte^{-E/(RT)}}$$

Where:

D = destruction removal efficiency (%)
R = the universal gas constant = 1.986 BTU/(lb-mol x °R)
E = activation energy for the HAP (BTU/(lb mol))
t = residence time (seconds)
V = the frequency factor for the HAP (seconds $^{-1}$)
T = the reaction temperature (°R)

[3] E. Roberts Alley, Air Quality Control Handbook, page 22.9

Figure 2 Theoretical HAP Destruction
(for a mix of HAPs found in Asphalt Roofing Line Emissions)



The purpose of the graph is to provide an approximate relative ranking of the performance characteristics of the various thermal oxidizers and afterburners in the database. It should be noted that this graph merely shows the theoretical relationship between destruction removal efficiency, residence time and temperature for two HAPs. Benzene and toluene were chosen because they are representative of HAPs sometimes found in the asphalt roofing manufacturing gas stream and because the constants E (activation energy, BTU/(lb mol)) and V (the frequency factor for the compound in seconds $^{-1}$) were available for these constituents. Sensitivity analysis of this equation with other combinations of HAPs shows that the composition of the HAPs being treated will change the slope of the sigmoidal curves, (they become flatter or steeper) but the relative performance of the thermal oxidizers (i.e., their comparative ranking in terms of D, % destruction removal efficiency) does not change.

By looking at the relative performance of the control devices plotted on Figure 2 and knowing that the Line 10 control device does *not* reduce HAP concentrations, it can be concluded that all of the control devices which are predicted to have a destruction removal efficiency lower than that of the Line 10 control device should not be considered thermal oxidizers. Rather, they should be considered afterburners.

Three important factors contributing to destruction removal efficiency are residence time, operating temperature and turbulence. It is not always feasible or safe to simply operate a control device at a higher temperature. As absolute temperature (measured in Rankin or

Kelvin) is increased, the volume occupied by the gas increases proportionately and residence time must decrease inversely (as the volume of the thermal oxidizer remains constant but the gas flow rate increases). Devices such as the Line 10 afterburner cannot be upgraded to operate at higher temperatures. In general, they have low residence times, and may have less than ideal mixing. Additionally, there are practical and safety considerations that make it infeasible or unsafe to increase the operating temperature substantially. The burner controls on these older units would need to be modified and, in many cases, combustion air fans replaced. Poor mixing design in the combustion chamber causes the energy consumption for higher temperatures to be non-linear, leading to greatly increased operating costs. The costs of burner redesign, combustion air modifications and combustion chamber modifications to improve turbulence often dictate total replacement of the control device rather than its modification.

Other Control Devices

Roofing production lines have a variety of other types of control equipment, and many of the lines are uncontrolled. These other control devices were installed principally to control particulate emissions, opacity and odor. ARMA endorses the conclusion stated by ERG, "The PM control devices used by the facilities are not expected to reduce gaseous HAP emissions."

Conclusion: MACT for Existing Roofing Lines

Accordingly, as fewer than 6% of the existing sources are controlled by thermal oxidizers, and as afterburners and particulate matter control devices do not significantly reduce HAP emissions, the MACT floor for existing sources is no control.

3.2.2 New Source MACT Floor for Roofing Lines

In order to establish new source MACT floor, it is necessary to determine the best-controlled similar source. Figure 2 would indicate that the best-controlled source is a thermal oxidizer on Line 6, which has a residence time of 0.5 seconds and an operating temperature of 1600°F. Rather than establish strict engineering design guidelines for temperature and residence time, ARMA recommends that EPA establish the emission limits in terms of pounds of an indicator parameter per ton of asphalt used. This will allow each roofing line operator to meet the emission limit in the most cost-effective way possible.

4.0 Consideration of Control Beyond the MACT Floor

This section contains an analysis of the control technologies that would be beyond the MACT floor (or BTF). Section 4.1 contains a discussion of the potential BTF control alternatives for asphalt blowing stills. Section 4.2 contains a similar discussion for asphalt roofing lines. Section 4.3 contains HAP emission estimates for each of the model plants described in the ERG report, and combines these emission estimates with the ERG cost estimates to calculate the cost-effectiveness of the BTF control technologies.

4.1 Asphalt Blowing Stills

As demonstrated in Section 3.1.1 of this document, the MACT floor for asphalt blowing stills is thermal oxidation. All existing sources currently operating are controlled by thermal oxidation. ARMA is aware of two potential BTF alternatives. First is a control device modification intended to improve removal of organic HAPs. In the ERG report (page 5) it was suggested that the existing thermal oxidizers could be run at 1600°F. The second BTF option relates only to those blowing stills that use a ferric chloride catalyst. For these units, a BTF option would be add some type of treatment or process modification to reduce emissions of hydrochloric acid. Each of these options is discussed below. ARMA believes that there is no justification for imposing a MACT more stringent than the MACT floor.

4.1.1 Increasing the Operating Temperature of Thermal Oxidizers

The ERG report (p. 5) states, "For the existing thermal oxidizers used to control emissions from blow stills, no capital costs were estimated since the assumption was made that facilities would be able to use their existing thermal oxidizers to comply with the NESHAP. Annual costs were estimated for additional natural gas and electricity consumption to increases the operating temperature from 1200°F to 1600°F."

As is evident from Figure 2, increasing the temperature at which a thermal oxidizer operates can improve the unit's destruction removal efficiency. However, in many cases it is not possible to operate a unit at higher temperatures for a sustained period of time. As noted in the Afterburner Systems Study[4], "Many units are subject to structural failure since thermal expansion stresses can be severe and many are not capable of operation at 1400 – 1500°F." Experience within the roofing industry indicates that without modification of the burner to accommodate the higher gas flow required, explosion is a possibility. Moreover, when the temperature is raised beyond the design temperature, in some cases it is very difficult to keep the unit operating. Potential consequences include rapid deterioration of the heat recovery tubes and refractory. Finally, some units, such as the thermal oxidizer at Fremont, are also used for heating oil. These units cannot be operated at higher temperatures without building a new unit to serve the current unit's process-related function. The cost effectiveness of operating the existing thermal oxidizers at higher temperatures is calculated in Section 4.3. As shown there, the costs per ton of HAP removed are very high.

[4] Rolke, et al, p. 6

4.1.2 Hydrochloric Acid Removal Technologies

The largest source of HAP emissions from asphalt blowing stills is HCl generated from those stills that use Ferric Chloride as a catalyst. To ARMA's knowledge, there are no effective technologies for the removal or reduction of HCl from blowing stills. In a similar MACT rulemaking for the Portland Cement Manufacturing Industry, EPA concluded that there were no feasible HCl controls, and therefore did not establish HCl standards. As stated in the preamble, EPA found that "the MACT floor for both new and existing sources was no control. Further, no cost-effective beyond the floor alternatives were identified." 64 FR 31919, June 14, 1999.

4.2 Asphalt Roofing Lines

For the following reasons, ARMA believes that it is not justifiable to require control beyond the floor for asphalt roofing lines:

- The average HAP emissions from roofing lines are very low.
- While effective for the destruction of HAPs, incineration causes other undesirable air quality impacts (such as the formation of NOx and greenhouse gases) and consumes significant energy.
- Because thermal oxidation is expensive and HAP emissions are low, the cost per ton of HAPs removed is extremely high and inconsistent with costs imposed in virtually all other MACT standards.
- A MACT that required control beyond the MACT floor would potentially apply only to those few sources collocated with other major sources. These sources would see significant increases in their cost structure, resulting in major inequities within the source category.

4.2.1 Emissions from Asphalt Roofing Lines are Very Low

The average emissions from roofing lines are very low. If these lines were not occasionally collocated with other major sources of HAPs, there would be no major sources within the asphalt roofing manufacturing subcategory. As can be seen from Table 2, the total potential emissions of all HAPs from a typical roofing plant is about 2 tons per year. A large, multi-line roofing plant would be about 6 tons per year.

4.2.2 Consideration of Other Air Quality Impacts and Energy Impacts

Because the MACT floor is no control, EPA's decision in establishing MACT for existing roofing lines is whether to require control beyond the MACT floor. As set forth in the Clean Air Act, the decision regarding whether to require a MACT more stringent than the MACT floor is made based on selection of the technology that provides the maximum degree of reduction of HAPs, taking into consideration the cost of achieving such emission reduction and any nonair quality health and environmental impacts and energy requirements. ARMA presents the following information relevant to this issue:

Thermal oxidation (a BTF option) is widely used to destroy organic compounds, but results in several adverse environmental and energy impacts. According to EPA's Air Pollution Technology Fact Sheet on Thermal Incinerators (http://www.epa.gov/ttn/catc/dir1/fthermal.pdf), "VOC destruction efficiency depends upon design criteria (i.e., chamber temperature, residence time, inlet VOC concentration, compound type, and degree of mixing). Most incinerators are designed to use natural gas as a fuel source. Incinerators emit oxides of nitrogen (NO_x) and CO_2 which contribute to global warming and ground level ozone formation. Additionally, thermal oxidizers treating low concentrations of VOCs require auxiliary fuels.

4.2.3 Costs of Thermal Oxidation

As acknowledged in EPA's Air Pollution Technology Fact Sheet (http://www.epa.gov/ttn/catc/dir1/fthermal.pdf) on Thermal Incinerators, "Thermal incinerator operating costs are relatively high due to supplemental fuel costs." Because HAP emissions from roofing lines are low and thermal oxidizer operating costs are high, the costs/ton of HAP removed are extraordinarily high.

Table 6 shows a summary of costs per ton of HAP removed for the roofing lines contained in the ERG model plant summary, assuming no ferric chloride catalyst asphalt processing is used. ARMA used the cost estimates used in the ERG report and the following assumptions in order to calculate the cost per ton of HAP removed:

- The HAP Emissions in tons/year are calculated from the emission factors developed in Table 2.
- Capital costs were converted to annual costs assuming the interest rate is 8% and the expected useful life of the thermal oxidizers is 15 years.
- For roofing lines, it is assumed that the destruction removal efficiency of the thermal oxidizers is 98%.
- For blowing stills, it is assumed that the modified thermal oxidizers improve HAP removal efficiency by 50%.

As can be seen from Table 6, the costs range from $187,000/ton of HAP removed to over $1,600,000 ton of HAP removed. The median cost is $436,000 per ton of HAP removed. These costs are extraordinarily high. A few BTF MACT standards have been established that required costs in excess of $400,000/ton of HAP removed. However, these have without exception been for technologies installed to provide control of nonorganic HAPs.

Table 6 Cost per ton of HAP Removed
No Catalyst

Model Plant Description	Process Units	Asphalt Through put (tpy)	HAP Emissions[5] (tpy)	HAP Emissions Reductions[6] (tpy)	Annual cost of capital + O&M[7]	Cost per ton of HAP removed[8]
Asphalt Processing only	A1	Total:	0.37	0.23	$147,544	$505,380
	Blowing Still	50,000	0.28	0.14		
	Asphalt Storage	50,000	0.09	0.09		
	A2	Total:	0.74	0.46	$155,619	$257,047
	Blowing Still	100,000	0.55	0.28		
	Asphalt Storage	100,000	0.19	0.18		
	A3	Total:	1.11	0.69	$234,825	$280,283
	Blowing Still	150,000	0.83	0.41		
	Asphalt Storage	150,000	0.28	0.27		
Oxidized asphalt storage + Fiberglass substrate line	B1/C1	Total:	1.69	1.66	$842,568	$435,990
	Asphalt Storage	50,000	0.09	0.09		
	FG Line	50,000	1.60	1.56		
	B2/C2	Total:	3.38	3.31	$1,500,753	$401,872
	Asphalt Storage	100,000	0.19	0.18		
	FG Line	100,000	3.19	3.13		
	B4/C4	Total:	6.76	6.62	$2,933,043	$392,965
	Asphalt Storage	200,000	0.37	0.37		
	FG Line	200,000	6.39	6.26		
Asphalt processing + Fiberglass substrate line	A1/C1	Total:	1.97	1.79	$933,451	$453,184
	Blowing Still	50,000	0.28	0.14		
	Asphalt Storage	50,000	0.09	0.09		
	FG Line	50,000	1.60	1.56		
	A2/C2	Total:	3.93	3.59	$1,760,146	$444,823
	Blowing Still	100,000	0.55	0.28		
	Asphalt Storage	100,000	0.19	0.18		
	FG Line	100,000	3.19	3.13		
	A4/C4	Total:	7.86	7.18	$3,645,331	$466,562
	Blowing Still	200,000	1.10	0.55		
	Asphalt Storage	200;000	0.37	0.37		
	FG Line	200,000	6.39	6.26		

[5] The HAP Emissions are from Table 2 above, Total HAP Emissions (tons/year)

[6] The HAP Emissions reductions are calculated by multiplying the HAP emissions by the expected removal efficiency of the control device: 98% for the thermal oxidizers on the roofing lines and 50% for the change in control efficiency for the increased operating temperature for the thermal oxidizers on the blow stills. If the blow stills were operating without catalyst, the HAP emissions would be higher, but because the thermal oxidizers do not remove HCl, the HAP Emissions reductions would not change.

[7] This is from the ERG report, Table 9. The Annual cost of capital + O&M is calculated by adding the Total Annual Cost to the annualized Total Capital Investment. The Total Capital Investment is annualized by assuming that the cost of capital is 8% and the control devices have a life of 15 years.

[8] The cost in $/ton of HAP removed =(Annual cost of capital + O&M) / HAP Emissions Reductions in tpy.

Table 6 (Continued) Cost per ton of HAP Removed

Model Plant Description	Process Units	Asphalt Through put (tpy)	HAP Emissions (tpy)	HAP Emissions Reductions (tpy)	Annual cost of capital + O&M	Cost per ton of HAP removed
Oxidized asphalt storage + Fiberglass substrate line + Organic substrate/multi-product line	B1/C1/D1	Total:	1.81	1.77	$1,605,730	$813,579
	Asphalt Storage	50,000	0.09	0.09		
	FG Line	50,000	1.60	1.56		
	Organic Line	5,000	0.12	0.12		
	B4/C1/D1	Total:	2.09	2.05	$1,216,481	$525,452
	Asphalt Storage	200,000	0.37	0.37		
	FG Line	50,000	1.60	1.56		
	Organic Line	5,000	0.12	0.12		
	B4/C2/D2	Total:	3.92	3.84	$2,374,434	$562,141
	Asphalt Storage	200,000	0.37	0.37		
	FG Line	100,000	3.19	3.13		
	Organic Line	15,000	0.35	0.35		
	B4/C3/D3	Total:	5.87	5.75	$3,919,415	$617,318
	Asphalt Storage	200,000	0.37	0.37		
	FG Line	150,000	4.79	4.69		
	Organic Line	30,000	0.71	0.69		
Asphalt processing + Organic substrate/multi-product line	A1/D2	Total:	0.72	0.58	$916,334	$1,384,125
	Blowing Still	50,000	0.28	0.14		
	Asphalt Storage	50,000	0.09	0.09		
	Organic Line	15,000	0.35	0.35		
	A2/D3	Total:	1.44	1.15	$1,738,029	$1,368,475
	Blowing Still	100,000	0.55	0.28		
	Asphalt Storage	100,000	0.19	0.18		
	Organic Line	30,000	0.71	0.69		
Asphalt processing + Fiberglass substrate line + Organic substrate/multi-product line	A2/C1/D1	Total:	2.45	1.86	$1,371,663	$660,853
	Blowing Still	100,000	0.55	0.28		
	Asphalt Storage	100,000	0.19	0.18		
	FG Line	50,000	1.60	1.56		
	Organic Line	5,000	0.12	0.12		
	A3/C3/D3	Total:	6.60	6.07	$4,863,522	$741,144
	Blowing Still	150,000	0.83	0.41		
	Asphalt Storage	150,000	0.28	0.27		
	FG Line	150,000	4.79	4.69		
	Organic Line	30,000	0.71	0.69		

Table 6 (Continued) Cost per ton of HAP Removed

Model Plant Description	Process Units	Asphalt Through put (tpy)	HAP Emissions (tpy)	HAP Emissions Reductions (tpy)	Annual cost of capital + O&M	Cost per ton of HAP removed
Asphalt processing + Fiberglass substrate line + Modified Bitumen Roofing Line	A2/C1/E1 Blowing Still Asphalt Storage FG Line Mod Bit	Total: 100,000 100,000 50,000 10,000	3.21 0.55 0.19 1.60 0.88	2.88 0.28 0.18 1.56 0.86	$1,247,003	$385,964
	A4/C4/E1 Blowing Still Asphalt Storage FG Line Mod Bit	Total: 200,000 200,000 200,000 10,000	8.74 1.10 0.37 6.39 0.88	8.04 0.55 0.37 6.26 0.86	$4,088,637	$466,770
	A5/C5/E2 Blowing Still Asphalt Storage FG Line Mod Bit	Total: 450,000 450,000 230,000 20,000	12.42 2.48 0.84 7.34 1.76	10.98 1.24 0.82 7.20 1.72	$8,177,275	$683,081
Oxidized asphalt storage + Organic substrate/multi-product line	B1/D1 Asphalt Storage Organic Line	Total: 50,000 5,000	0.21 0.09 0.12	0.21 0.09 0.12	$410,678	$1,601,014
Oxidized asphalt storage + Fiberglass substrate line + Modified bitumen roofing line	B1/C1/E2 Asphalt Storage FG Line Mod Bit	Total: 50,000 50,000 20,000	3.45 0.09 1.60 1.76	3.38 0.09 1.56 1.72	$1,147,896	$298,249
Modified bitumen roofing line	E1 Mod Bit Asphalt Storage	Total: 10,000 10,000	0.90 0.88 0.02	0.88 0.86 0.02	$286,139	$252,704
	E2 Mod Bit Asphalt Storage	Total: 20,000 20,000	1.79 1.76 0.04	1.76 1.72 0.04	$411,781	$187,820

As thermal oxidizers are not effective for the removal of HCl emissions, the cost per ton of HAPs removed for blowing stills using ferric chloride would be very similar to those shown in Table 6.

4.2.4 Competitive Implications

Very few roofing lines are collocated with major sources of HAPs. Emissions from these sources are low, generally less than 3 tons per plant per year. If EPA establishes a beyond-the-MACT-floor requirement for roofing lines, only those few collocated sources would be affected. These sources would be required to install thermal oxidation, while an identical plant located across the street and owned by a competitor would operate without controls. The controlled sources would see significant increases in their cost-structure, causing inequities within the source category. Such inequities are of particular concern in an industry that is very competitive, produces a commodity product and is undergoing significant consolidation.

5.0 Conclusions

The asphalt roofing industry emits very low amounts of Hazardous Air Pollutants. All existing blowing stills are controlled with thermal oxidizers; thus the MACT floor for existing blowing stills is thermal oxidation. The MACT floor for new blowing stills is also thermal oxidation. The MACT floor for existing asphalt roofing lines is no control, while for new lines the MACT floor technology is thermal oxidation. The potential beyond-the-floor alternative of thermal oxidation for existing asphalt roofing lines consumes significant energy, produces greenhouse gases, poses unfair competitive implications and is not cost-effective. EPA therefore should not set beyond-the-floor standards. Moreover, no feasible beyond the floor alternatives have been identified for blowing stills.

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ARMA MACT Analysis, Appendices

Appendix A

See the enclosed diskette. It contains a file named ARMAHAPs.xls.

Emissions Data Table of Contents

Data used in developing emissions from the model plant.

	Date	Workbook In ARMA-HAPs.xls	Workbook Rows	Source	Plant	Company
A.	8/17/98	No-Cat-Ox-Still	19 - 158	Converter	Oxford	CertainTeed
B.	5/6/99	Trumbull-Still	18 – 261	Converter	Jessup	O-C
C.	5/6/99	Loading	12 – 123	Loading	Jessup	O-C
D.	5/6/99	Flux Tank-data	13 – 34	Loading	Jessup	O-C
E.	3/9/99	Frem-Tanks	12 – 36	Laminator	Fremont	Celotex
F.	3/9/99	Frem-Tanks	37 – 59	Lam Day Tank	Fremont'	Celotex
G.	3/9/99	Frem-Tanks	83 – 106	SD Exhaust	Fremont	Celotex
H.	3/9/99	Frem-Tanks	108 – 130	SD Day	Fremont	Celotex
I.	5/6/99	OxTanks	18 – 106	Oxidized Tank	Jessup	O-C
J.	2/9/99	OxTanks	107 - 262	Oxidized Tank	Minneap	O-C
K.	3/12/99	Frem-Tanks	58 – 179	Tank Farm	Fremont	Celotex
L.	5/11/99	Fred-Sat	3 – 297	Satuarator	Frederick	TAMKO
M.	3/9/99	FremHMix	12 – 101	Horizontal Mix	Fremont	Celotex
N.	3/9/99	FremVMix	12 – 101	Vertical Mixer	Fremont	Celotex
O.	2/9/99	Minn-HIRT	29 – 317	Coater	Minneap	O-C
P.	3/9/99	Frem-Coat	12 – 101	Coater	Fremont	Celotex
Q.	5/11/99	Frederick-Coat	17 – 265	Coater	Frederick	TAMKO
R.		Port Arth Inc	12 – 23	Mod Bit Line	Port Arthur	U.S. Intec
S.		Port Arth Tank	19 – 28	APP Holding	Port Arthur	U.S. Intec
T.		Port Arth Tank	29 – 33	APP Mixing	Port Arthur	U.S. Intec
U.		Port Arth Tank	3 – 12	SBS Holding	Port Arthur	U.S. Intec
V.		Port Arth Tank	13 – 18	SBS Mixing	Port Arthur	U.S. Intec
W.	8/17/98	Cat-Ox-Still	19 – 205	Converter	Oxford	CertainTeed
X.	1994	Cat-Ox-Still	208 – 242	Converter	Linnton	O-C
Y.	1995	Cat-Ox-Still	247	Converter	Medina	O-C
Z.	1999	Cat-Ox-Still	248	Converter	Minneap	O-C

Other data included in ARMAHAPs.xls, but not required to calculate the model plant HAP emissions.

Date	Workbook	Rows	Source	Plant	Company
3/9/99	Roofing-Inc	18 - 155	RTO at 1400	Fremont	Celotex
3/9/99	Roofing-Inc	156 - 452	RTO at 1600	Fremont	Celotex
2/9/99	Roofing-Inc	453 - 692	RTO	Minneap	O-C
2/9/99	Minn-Complete	18 - 623	RTO	Minneap	O-C
	Port Arth Inc	2 – 11	RTO	Port Arthur	U. S. Intec

These emission reports have already been submitted to EPA, and are submitted here as duplicates

Appendix B

Appendix B contains a report from Grant Plummer explaining the rationale for removal of the Shakopee data.

January 11, 2000

Concentration Determinations from FTIR Spectra Collected at Two Asphalt Roofing Manufacturing Facilities

Prepared by:

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Rho Squared

Prepared for:

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General

In August 1998, Midwest Research Institute (MRI) and Entropy, Inc. (Entropy) performed independent extractive FTIR emissions tests at two asphalt roofing manufacturing facilities. In November 1999, Mr. Todd Grosshandler of Enthalpy Analytical, Inc. (Enthalpy) requested that I perform qualitative and quantitative analyses of the resulting infrared spectra. The digital spectra and written descriptions of them were provided by Dr. Thomas Geyer of MRI and Dr. Thomas Dunder of Entropy. Mr. Grosshandler also provided me a summary of the analytical results and mass emission rates.

The spectral data sets consist of absorbance spectra recorded at various sampling locations at the two production plants, referred to here as the "Oxford" and "Shakopee" facilities. Each set includes a number of calibration transfer standard (CTS) spectra of ethylene in nitrogen; I used these spectra to determine the absorption pathlengths of the FTIR systems used in the tests. Each set also contains spectra of both "spiked" and "unspiked" samples; at the request of Mr. Steve Eckard of Enthalpy, I have considered only the unspiked samples in this work.

Compounds of Interest

For each facility, Mr. Grosshandler identified several compounds which are of the greatest interest. They are, for the Oxford facility, HCl, hexane, and toluene (denoted below as HCL, HEX, and TOL). For the Shakopee facility, Mr. Grosshandler identified HCl, the meta, - ortho-, and para- isomers of xylene, and formaldehyde. These compounds are denoted below as HCL, M-X, O-X, P-X, and H2CO. The data summary provided by Mr. Grosshandler indicates that the compounds phenol (PHE) and methanol (MOH) were detected in some of the infrared data. My examination of the spectra indicates the additional presence, in some samples, of methane (CH4). As is normally the case, all the spectra contain absorbance features of water (H2O) and carbon dioxide (CO2), which I also included in my analyses.

Analytical Program

References 1 through 5 comprise a thorough description of the "classical least squares" (CLS) technique for analyzing FTIR absorbance spectra. Using the programming language ARRAY BASIC™ (GRAMS, Version 3.02, Galactic Industries Corporation, Salem, New Hampshire), I have prepared a computer program (4FIT, version MD16, described in Reference 6) to perform this technique. The terminology and basic analytical approach employed in this work are described in the "EPA FTIR Protocol" (Reference 7). The program determines baseline parameters along with the compound concentrations; I employed both linear and quadratic baseline models in this work, as described below. The program also scales concentration results to reflect differences in concentration, absorption pathlength, gas temperature, and gas pressure between the reference and sample spectra.

The program 4FIT provides the standard 1σ uncertainty in each concentration. However, all uncertainties quoted below are equal to two times the calculated 1σ values. The program also calculates the residual spectra (the difference between the observed and least squares fit absorbance values) for each analytical region. After determining concentration values and uncertainties for each compound in each analytical region for each sample spectrum, the program rejects compounds from each analytical region if either a) its determined concentration is negative or b) the 2σ uncertainty in its concentration is greater than the (positive) determined concentration. If a compound is rejected from a region for a particular sample spectrum, its concentration is recorded as exactly zero in the output file along with the related 2σ uncertainty from the original fit. Such uncertainty values are conservative upper limits on the uncertainty of the reported zero concentration values. I also performed several preliminary analyses which employed the use of the 4σ uncertainty as the rejection criterion, but founds the results inferior to those of the 2σ criterion described above.

Reference Spectra

The original source of the quantitative reference spectra employed in this work is the EPA FTIR spectral library of Hazardous Air Pollutants (HAPs; see Reference 8). The spectral resolution of the EPA library is 0.25 cm^{-1}, so it was necessary to de-resolve the spectra for use in this analysis of the field test spectra. For this work, I used the "AEDC Deresolving Program" (preliminary version 2; see Reference 8) developed by EPA to form absorbance spectra at both 1 and 2 cm^{-1} spectral resolutions, all with Norton-Beer (medium) apodization. Table 1 lists the information regarding the original spectra I employed. I assigned the extensions "a1m" and "a2m" to the deresolved files at 1 and 2 cm^{-1}, respectively.

Data Sets, Run Designations, Test Conditions, and Absorption Pathlengths

From the information supplied with the spectral data, I formed a number of separate data sets and assigned each a "run designation." The file names, field test conditions, absorption pathlengths, and run designations for each data set are given in Tables 2 through 4. The quoted absorption pathlengths were determined in CLS analyses from 871 to 1029 cm^{-1}, with a linear baseline correction, using the (deresolved) EPA CTS spectrum cts0318b.asf (393 K, 11.25 m, 100 ppm, 1.0 atm).

Analytical Techniques

The program 4FIT allows the analyst to select a number of analytical regions and to specify the reference spectra to be used in determining the corresponding compound concentrations in each region. Table 5 identifies and lists the details of the various analytical regions I employed in this work.

The program examines the analysis results and, under the circumstances described above, automatically removes compounds from consideration in a particular analytical region on the basis of those results. The data I examined fall into the three distinct sets described in Tables 2 through 4; these sets were recorded with different field instruments and at two different spectral resolutions. I formulated and tested several different analytical techniques on nearly all the data, and found that no one technique provided optimal results for all of them. The results reported here were based on a different analysis technique for each of the three data sets, and they are referred to in this report and the "c," "e," and "f" analyses. (Note that the "Fit" and "Results" file name listed in Tables 2 through 4 contain one of the characters "c," "e," and "f" as an identifier for the analysis with which they are associated.) Table 6 lists the analytical regions employed in the three different analyses and .indicates which compounds were initially included in each regional analysis. Note, however, that some of the final results presented below were generated in analyses from which some of the compounds were subsequently removed from consideration.

The two spectral regions generally referred to as the "C-H stretch" (CH) and "fingerprint" (FP) regions run from roughly 2600 to 3500 cm^{-1} and 600 to 1500 cm^{-1}, respectively. These spectral regions are often used in FTIR analyses because of the relatively common and intense absorption bands which occur there, and because they fall between regions of intense water and carbon dioxide absorption. Illustrated in Figure 1 are the HAP reference spectra and the analytical regions I used in this work. Note that the y-axis scale for each of the traces in Figure 1 has been independently set, so the various traces are not comparable in any quantitative sense.

The process of selecting the best analytical regions for a given gas matrix is an iterative one. It involves visual inspections of the sample spectra, considerations of the quality and consistency of the analytical results obtained for the compounds in various regions, visual evaluations of the residual spectra from each analysis, and adjustment of the analysis parameters. The quality of the analysis is often limited by the accuracy with which the sample absorption of the major gas constituents is modeled by the available reference spectra; it is therefore preferable to use reference spectra recorded on the field test instruments themselves, especially for the strong absorbers in the samples. Because the H2O and CO2 spectra available for this analysis were recorded on a various laboratory instruments, the spectral mismatch (between sample and reference spectra) for these two compounds is often the largest source of error and uncertainty in the results.

In all the analyses described below, I chose to omit the xylene isomers from the CH region calculations. This is because qualitative examinations of the sample data show no clear evidence of these compounds in the more sensitive FP region, and because of the similarities between the xylene isomers in the CH region.

I found the analysis referred to as "c" suitable for the Oxford data sets designated as runs 822R1c, 822R2c, and 822R3c, which often show clear evidence of MOH content. However, inclusion of MOH in the CH region was unsuitable for all the other (low- or zero-methanol) sample spectra. I therefore devised the "e" analysis, which I applied to the majority of the data. This analysis differs from the "c" analysis in 1) the removal of

MOH from CH1 and CH2 regions and 2) the addition of a high-level CO2 spectrum in the FP regions. This first choice was supported by improvements in the concentration uncertainties for the CH regions. The second, which led to only marginal improvements, was motivated by the presence of the strong 720 cm^{-1} CO2 transition found in the residual spectra. For many of the data, this feature was not well modeled by the available reference CO2 spectra, and the quality of the FP results is therefore quite variable, especially for the three xylene isomers.

The "f" analysis applied to the Shakopee data differs from the "e" analysis in that it provides essentially separate TOL and HEX analyses in the CH region. Figure 2 illustrates my reasons for making this adjustment, which I affected by creating the distinct CH4 and CH5 regions; I also employed quadratic (rather than linear) baseline corrections in these regions to account for the HEX "shoulder" at 3000 cm^{-1}. (Note, again, that the y-axis scale for each of the traces in Figure 2 has been independently set.) The CH1 and CH2 residual spectra in Figure 2 indicate over-subtraction of both TOL and HEX in the "e" analysis. The TOL subtraction is clearly improved in the CH4 residual of the "f" analysis. Figure 2 also indicates that both the "e" (CH1 and CH2) and "f" (CH5) analyses over-subtract the relatively narrow HEX features at 2890 and 2880 cm^{-1}. This is possibly caused by the presence in the samples of higher-weight, hexane-like compounds which lack these narrower features.

Results and Discussion

Tables 7 though 15 present the results of the CLS analyses described above. Variations in the accuracy of the reference spectra resulted in varying quality of these results for different combinations of field spectrometers, analyte compounds, and analytical regions. In some cases, I selected one of a number of ambiguous CLS results for each compound, according to the criteria listed below. These criteria were applied to the results averaged over associated run designations and to the averages of the "isolated" spectral sets not clearly associated with any other run designation.

1) Visual examinations of the sample and residual spectra were sometimes in clear conflict with the indicated CLS concentrations and uncertainties. In these cases, I report zero concentrations and unknown concentration uncertainties.
2) When all regions indicate zero concentration: I report the zero concentration and the lowest concentration uncertainty.
3) When a single region indicates a non-zero concentration: I report the non-zero concentration (and the associated uncertainty), except when visual examinations fail to support the CLS results (see criterion 1 above).
4) When more than one region yields a non-zero concentration: I report the non-zero concentration (and the associated uncertainty) possessing the lowest associated *fractional* uncertainty, except when a) visual examinations fail to support the CLS results (see criterion 1 above) or b) visual examinations and CLS analyses support the results indicated in some other region resulting in non-zero concentrations.

Please do not hesitate to contact me if I can provide you with any additional results or details.

Sincerely,

Grant M. Plummer, Ph.D.

References

1. D.M. Haaland and R.G. Easterling, "Improved Sensitivity of Infrared Spectroscopy by the Application of Least Squares Methods," Appl. Spectrosc. 34(5):539-548 (1980).

2. D.M. Haaland and R.G. Easterling, "Application of New Least-Squares Methods for the Quantitative Infrared Analysis of Multicomponent Samples," Appl. Spectrosc. 36(6):665-673 (1982).

3. D.M. Haaland, R.G. Easterling and D.A. Vopicka, "Multivariate Least-Squares Methods Applied to the Quantitative Spectral Analysis of Multicomponent Samples," Appl. Spectrosc. 39(1):73-84 (1985).

4. W.C. Hamilton, Statistics in Physical Science, Ronald Press Co., New York, Chapter 4 (1964).

5. P.R. Griffiths and J.A. DeHaseth, Fourier Transform Infrared Spectroscopy, John Wiley and Sons, New York, ISBN 0-471-09902-3 (1986).

6. G. M. Plummer and W. K. Reagen, "An Examination of a Least Squares Fit FTIR Spectral Analysis Method," Air and Waste Management Association, Paper Number 96-WA65.03 (1996).

7. "Protocol for the Use of Extractive Fourier Transform Infrared Spectrometry for the Analyses of Gaseous Emissions from Stationary Sources," Addendum to Method 320, U.S. Environmental Protection Agency (1999).

8. See the EPA web site http://www.epa.gov/ttn/emc/ftir/data.html to download the HAP spectra. The site http://www.epa.gov/ttn/emc/ftir/tools.html provides a version of the AEDC spectral deresolution program (as of 1/08/00).

Table 1. Compound Abbreviations and Reference Spectral File Information

Compound Name	Abbreviation	Original Reference Spectra	T (K)	L (m)	C (ppm)	P (atm)
Ethylene	ETY	cts0318b.asf	393	11.25	100	1.0
Phenol	PHE	131b4anf.asf	373	2.25	101.3	1.0
Toluene	TOL	153a4ana.asf	298	3.0	499	1.0
Hexane	HEX	095a4asd.asf	298	3.0	101.3	1.0
Formaldehyde	H2CO	087b4ana.asf	373	11.25	100	1.0
Hydrogen chloride	HCL	097b4as(a,b).asf[A]	373	2.25	221	1.0
Methanol	MOH	104a4asd.asf	298	3.0	100	1.0
O-Xylene	O-X	171a4asa.asf	298	3.0	499	1.0
M-Xylene	M-X	172a4ara.asf	298	3.0	485	1.0
P-Xylene	P-X	173a4asa.asf	298	3.0	502	1.0
Methane	CH4	ch4_53s.asf	298	37.7	1	1
Water	H2O	194hsub.asf	345	4.66	1	1
Carbon Dioxide (low)	CO2lo	193b4a_b.asf	345	4.66	1	1
Carbon Dioxide (high)	CO2hi	193c1bs1.asf	345	4.66	1	1

[A]The average of these two files (097avh1.spc) was used in the CLS analysis.

Table 2. Oxford Data Sets at 1.0 cm^{-1} Resolution[A]

Start File	Time	Stop File	Time	Input File (*.csv)	# Files	T (K)	P (atm)	L (m)	Fit File (*.fit)	Result File (*.xls)	Run Designation
18170025	10:22	18170050	11:07	817_01	26	394	1.018	7.18	OR397e	R40e_17a	817R1
18180001	9:26	18180063	11:38	818_01	63	394	1.018	7.18	OR397e	R40e_18a	818R1
18180129	13:30	18180165	13:58	818_02	37	394	1.018	7.18	OR397e	R40e_18a	818R2
18190070	10:13	18190078	10:27	819_01	9	394	1.018	7.18	OR397e	R40e_19c	819R0
18190126	12:54	18190237	16:30	819_02	112	394	1.018	7.18	OR397e	R40e_19b	819R1
18190238	17:03	18190262	17:47	819_03	25	394	1.018	7.18	OR397e	R40e_19b	819R2
18190263	17:52	18190351	20:30	819_04	89	394	1.018	7.18	OR397e	R40e_19b	819R3
18210002	14:20	18210011	14:35	821_01	10	342	0.999	4.75	OR345e	R40e_21a	821R1
18220006	10:10	18220015	10:29	822_r1s	10	333	1.000	4.75	OR335e	R40e_22a	822R1a
18220016	10:29	18220025	10:47	822_r1c	10	333	1.000	4.75	OR335e	R40e_22b	822R1b
18220026	10:50	18220034	11:06	822_r1s	9	333	1.000	4.75	OR335e	R40e_22a	822R1a
18220035	11:08	18220043	11:24	822_r1c	9	333	1.000	4.75	OR335e	R40e_22b	822R1b
18220045	12:24	18220057	12:46	822_r2s	13	333	1.000	4.75	OR335e	R40e_22a	822R2a
18220058	12:44	18220067	13:06	822_r2c	10	333	1.000	4.75	OR335e	R40e_22b	822R2b
18220068	13:09	18220077	13:27	822_r2s	10	333	1.000	4.75	OR335e	R40e_22a	822R2a
18220078	13:29	18220081	13:37	822_r2c	4	333	1.000	4.75	OR335e	R40e_22b	822R2b
18220086	14:25	18220094	14:41	822_r3s	9	333	1.000	4.75	OR335e	R40e_22a	822R3a
18220095	14:43	18220104	15:00	822_r3c	10	333	1.000	4.75	OR335e	R40e_22b	822R3b
18220105	15:03	18220113	15:19	822_r3s	9	333	1.000	4.75	OR335e	R40e_22a	822R3a
18220114	15:22	18220119	15:32	822_r3c	6	333	1.000	4.75	OR335e	R40e_22b	822R3b

[A]The second through the fourth characters of the file name indicate the date on which the file was created; for example, the file 1817025 was created on 8/17.

Table 3. Oxford 8/22/98 Data Sets at 2.0 cm^{-1} Resolution

Start File	Time	Stop File	Time	Input File (*.csv)	# Files	T (K)	P (atm)	L (m)	Fit file (*.fit)	Result File (*.xls)	Run Designation
18220006	10:10	18220063	11:25	822d_01	58	345	1.043	4.66	OD345c	D20C_2	822R1c
18220086	12:50	18220123	13:37	822d_02	38	345	1.043	4.66	OD345c	D20C_2	822R2c
18220129	14:25	18220182	15:32	822d_03	54	345	1.043	4.66	OD345c	D20C_2	822R3c

Table 4. Shakopee Data Sets (1.0 cm^{-1} Resolution) from 8/2/98 and 8/3/98[A].

Start File	Time	Stop File	Time	Input File (*.csv)	# Files	T (K)	P (atm)	L (m)	Fit File (*.fit)	Result File (*.xls)	Run Designation
fsamp100	8:46	fsamp115	9:45	fr1	16	394	1	19.2	SR39119F	R40F_02a	802R1
fsamp202	11:55	fsamp216	12:50	fr2	15	394	1	19.2	SR39119F	R40F_02a	802R2
fsamp300	14:47	fsamp312	15:39	fr3	13	394	1	19.2	SR39119F	R40F_02a	802R3
fsamp400	16:14	fsamp414	17:10	fr4	15	394	1	19.2	SR39119F	R40F_02a	802R4
osamp100	9:21	fsamp109	10:19	or1	10	394	1	19.2	SR39119F	R40F_03a	803R1
osamp200	12:55	fsamp210	14:14	or2	11	394	1	19.2	SR39119F	R40F_03a	803R2
osamp300	15:40	fsamp310	16:34	or3	11	394	1	19.2	SR39119F	R40F_03a	803R3

[A]The spectral file header information indicates that these data were recorded on 8/1/ and 8/2/98.

Table 5. Analytical Regions

Analytical Region	Lower Limit (cm^{-1})	Upper Limit (cm^{-1})	Baseline Correction
CH1	2822	3143	Linear
CH2	2828	3008	Linear
CH3	2697	2832	Linear
CH4	2997	3143	Quadratic
CH5	2828	2981	Quadratic
FP1	1123	1280	Linear
FP2	700	818	Linear
FP3	969	1104	Linear

Table 6. Use of Analytical Regions in "c", "e,", and "f" Versions of the CLS Analyses

Analytical Region	PHE	TOL	HEX	H2CO	HCL	MOH	O-X	M-X	P-X	CH4	H2O	CO2 lo	CO2 hi
CH1		c e	c e		c e	c				c e	c e		
CH2		c e	c e	c e	c e	c				c e	c e		
CH3		c e		c e f	c e f					c e f	c e f		
CH4		f			f					f	f		
CH5			f	f	f					f	f		
FP1	c e f										c e f	c e f	e f
FP2	c e f	c e f					c e f	c e f	c e f		c e f	c e f	e f
FP3	c e f	c e f	c e f	c e f		c e f					c e f	c e f	e f

Figure 1. Reference Spectra and Analytical Regions

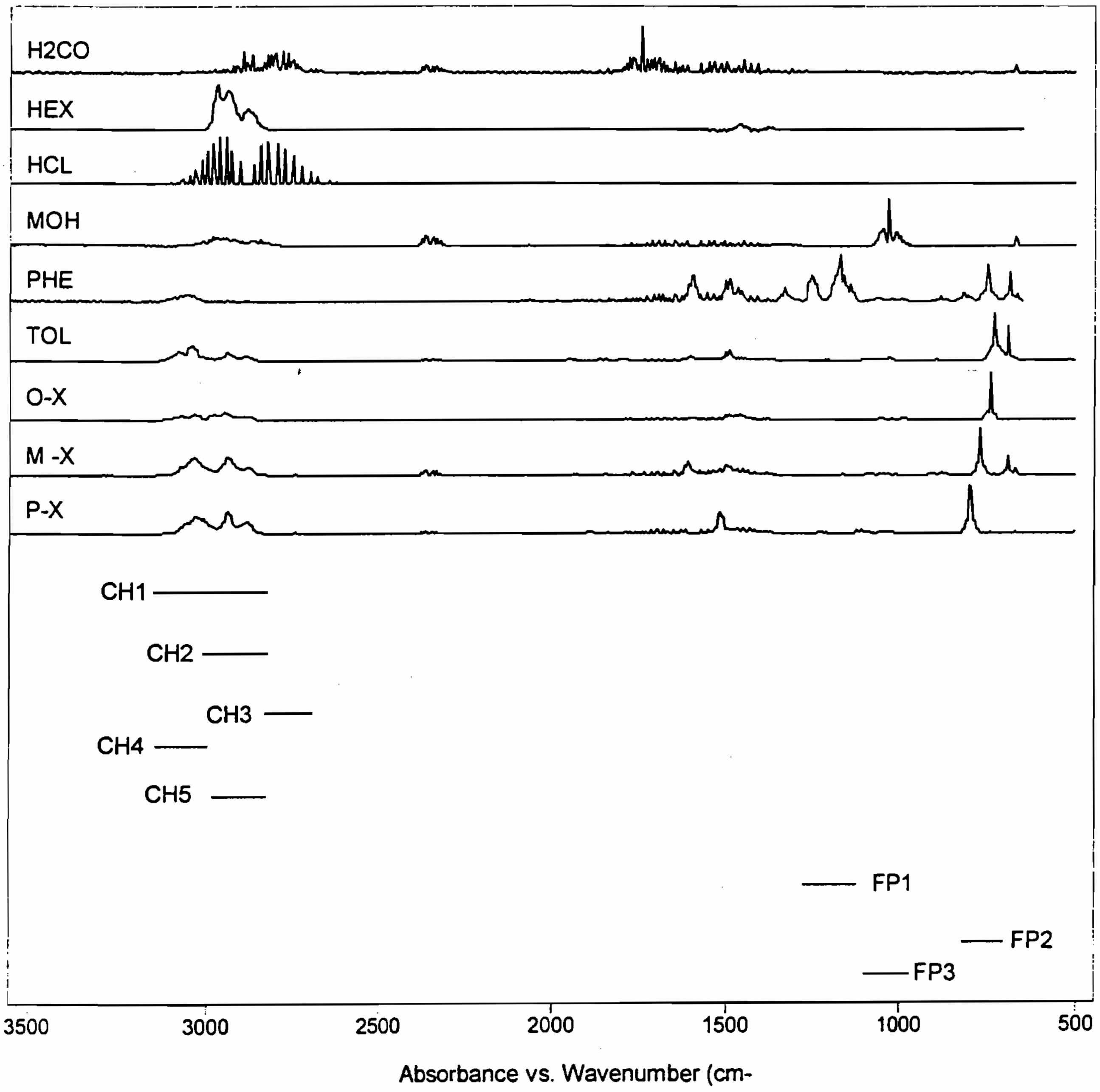

Figure 2. Details of HEX and TOL Spectra in CH Analytical Regions

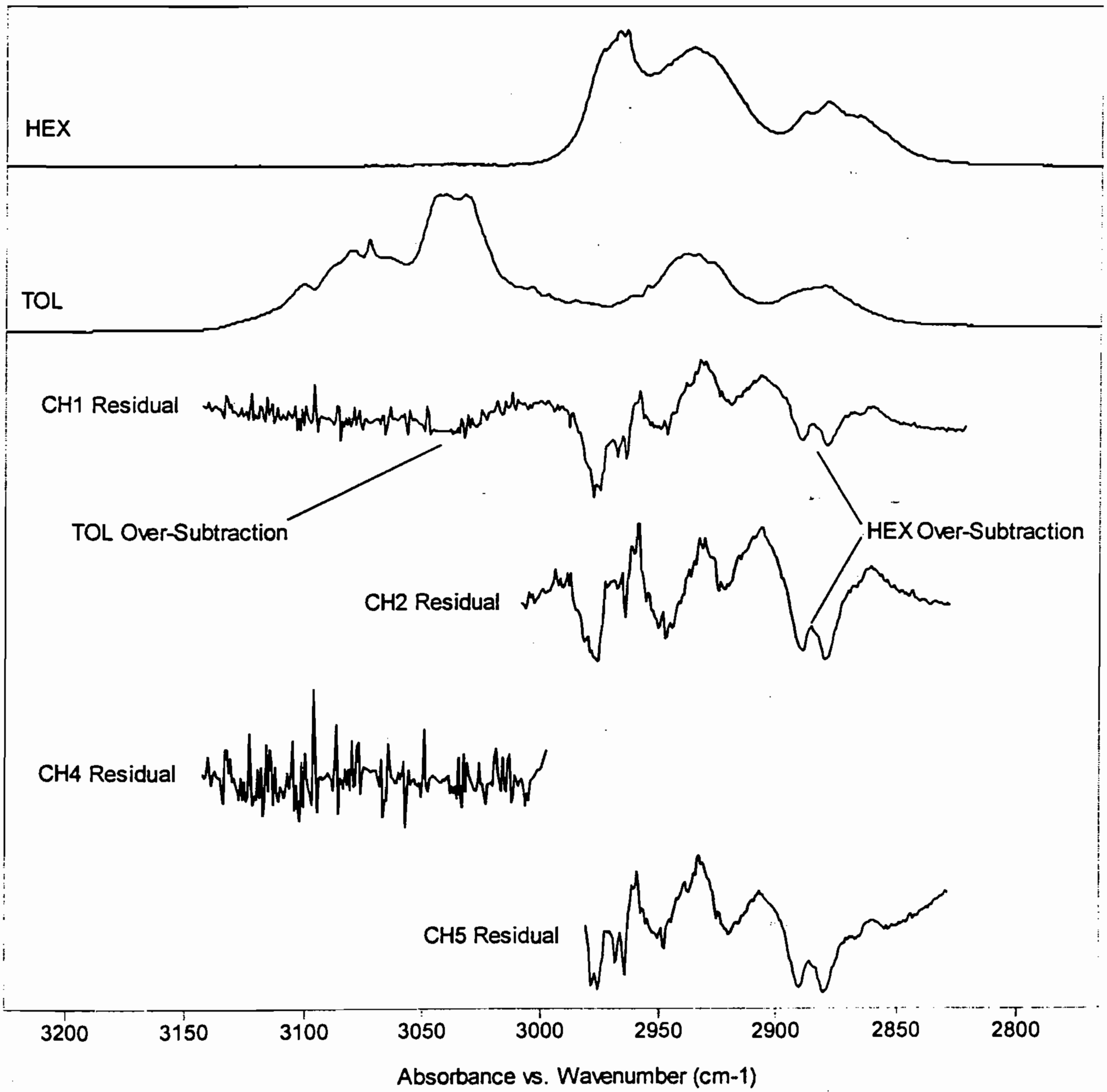

Table 7. Oxford 8/17 and 8/18 Results by Run Designation

	817R1 (ppm)[A]			818R1 (ppm)[A]			818R2 (ppm)[A]			818 AV (ppm)[B]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP1	5.9	4.1	FP1	6.6	5.6	FP1	4.2	4.5	FP1	5.4	5.1
TOL	CH1	13.9	11.7	CH1	3.0	11.3	CH1	0	11.6	CH1	1.5	11.5
HEX	CH1	14.1	1.9	CH1	13.7	1.9	CH1	0	1.9	CH1	6.8	1.9
H2CO	CH3	9.6	2.3	CH3	33.9	4.8	CH3	0	4.2	CH3	17.0	4.5
HCL	CH3	20.8	2.1	CH3	73.4	4.4	CH3	98.1	3.8	CH3	85.7	4.1
MOH	FP3	0	1.5	FP3	0.2	1.6	FP3	0	0.8	FP3	0.1	1.2
O-X	FP2	0	66	FP2	74	50	FP2	228	41	FP2	0	U
M-X	FP2	0	180	FP2	77	140	FP2	118	116	FP2	0	U
P-X	FP2	0	138	FP2	0	107	FP2	0	93	FP2	0	U

[A]Averages over spectral files with this run designation.
[B]Average of 818R1 and 818R2 results.
U indicates that the CLS uncertainties are inconsistent with visual examinations of the spectra, and therefore unknown.

Table 8. Oxford 8/19 Results (Partial) by Run Designation

	819R1 (ppm)[A]			819R2 (ppm)[A]			819R3 (ppm)[A]			819 AV (ppm)[B]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP1	22.0	4.1	FP1	13.1	4.2	FP1	3.4	4.0	FP1	12.8	4.1
TOL	CH1	20.3	13.9	CH1	3.7	13.6	CH1	0.2	10.9	CH1	8.1	12.8
HEX	CH2	52.5	1.7	CH2	12.0	1.5	CH2	0.6	1.2	CH2	21.7	1.5
H2CO	CH3	131	7.0	CH3	80.8	4.6	CH3	9.5	3.7	CH3	73.6	5.1
HCL	CH3	34.3	6.5	CH3	85.7	4.3	CH3	91.3	3.2	CH3	70.4	4.7
MOH	FP3	0	3.2	FP3	0	3.0	FP3	0	0.9	FP3	0	2.3
O-X	FP2	0	63	FP2	0	43	FP2	105	36	FP2	0	U
M-X	FP2	95	167	FP2	213	116	FP2	151	102	FP2	0	U
P-X	FP2	0	131	FP2	0	90	FP2	0	78	FP2	0	U

[A]Averages over spectral files with this run designation.
[B]Average of 819R1, 819R2, and 819R3 results.
U indicates that the CLS uncertainties are inconsistent with visual examinations of the spectra, and therefore unknown.

Table 9. Oxford 8/19 (Partial) and 8/21 Results by Run Designation

Compound	819R0 (ppm)[A] region	conc.	2σ unc.	821R1 (ppm)[A] region	conc.	2σ unc.
PHE	FP1	0	1.9	FP1	0	1.5
TOL	CH1	0	3.3	CH1	1.2	3.9
HEX	CH2	0	0.3	CH2	10.6	0.4
H2CO	CH2	1.8	3.2	CH2	0.4	4.1
HCL	CH3	6.7	1.1	CH3	2.3	1.6
MOH	FP3	0	0.2	FP3	0	0.5
O-X	FP2	0	U	FP2	0	1.5
M-X	FP2	0	U	FP2	0	4.2
P-X	FP2	0	U	FP2	0	3.2

[A]Averages over spectral files with this run designation.
U indicates that the CLS uncertainties are inconsistent with visual examinations of the spectra, and therefore unknown.

Table 10. Oxford 8/22 Location "a" Results by Run Designation

Compound	822R1a (ppm)[A] region	conc.	2σ unc.	822R2a (ppm)[A] region	conc.	2σ unc.	822R3a (ppm)[A] region	conc.	2σ unc.	822a AV (ppm)[B] region	conc.	2σ unc.
PHE	FP1	11.9	1.9	FP1	45.7	4.6	FP1	13.8	1.9	FP1	23.8	2.8
TOL	FP2	0	2.6	FP2	0	2.9	FP2	0	2.4	FP2	0	2.6
HEX	CH2	29.9	1.4	CH2	67.8	4.0	CH2	31.2	1.2	CH2	43.0	2.2
H2CO	CH3	0.3	1.9	CH3	14.9	4.6	CH3	5.6	2.2	CH3	7.0	2.9
HCL	CH3	0	1.7	CH3	0	4.3	CH3	0.1	2.0	CH3	0.0	2.7
MOH	FP3	3.7	0.7	FP3	25.9	2.5	FP3	0.7	0.9	FP3	10.1	1.4
O-X	FP2	0	1.5	FP2	0	1.6	FP2	0	1.3	FP2	0	1.5
M-X	FP2	0	4.1	FP2	0	4.4	FP2	0	3.7	FP2	0	4.1
P-X	FP2	0	3.1	FP2	0	3.4	FP2	0	2.8	FP2	0	3.1

[A]Averages over spectral files with this run designation.
[B]Average of 822R1a, 822R2a, and 822R3a results.

Table 11. Oxford 8/22 Location "b" Results by Run Designation

	822R1b (ppm)[A]			822R2b (ppm)[A]			822R3b (ppm)[A]			822b AV (ppm)[B]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP1	0.2	1.7	FP1	0.5	1.5	FP1	0	1.6	FP1	0.2	1.6
TOL	FP2	0	2.6	FP2	0	2.3	FP2	0	2.4	FP2	0	2.4
HEX	CH2	16.9	0.5	CH2	17.7	0.5	CH2	16.0	0.5	CH2	16.9	0.5
H2CO	CH3	2.5	1.6	CH3	0.9	1.5	CH3	0.4	1.5	CH3	1.3	1.6
HCL	CH3	0	1.5	CH3	0.7	1.4	CH3	0.6	1.4	CH3	1.4	0.4
MOH	FP3	0	0.5	FP3	0	0.4	FP3	0	0.4	FP3	0	0.5
O-X	FP2	0	1.5	FP2	0	1.3	FP2	0	1.7	FP2	0	1.4
M-X	FP2	0	4.0	FP2	0.3	3.6	FP2	0	3.7	FP2	0.1	3.8
P-X	FP2	0	3.1	FP2	0	2.8	FP2	0	2.8	FP2	0	2.0

[A]Averages over spectral files with this run designation.
[B]Average of 822R1b, 822R2b, and 822R3b results.

Table 12. Oxford 8/22 Location "c" Results by Run Designation

	822R1c (ppm)[A]			822R2c (ppm)[A]			822R3c (ppm)[A]			822c AV (ppm)[B]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP1	3.5	1.4	FP1	11.2	1.6	FP1	3.6	1.1	FP1	6.1	1.3
TOL	CH1	9.6	4.8	CH1	9.1	6.5	CH1	9.8	4.9	CH1	9.5	5.4
HEX	CH2	24.7	0.8	CH2	35.9	1.1	CH2	26.6	1.0	CH2	29.0	1.0
H2CO	CH3	0.5	1.2	CH3	5.3	2.0	CH3	3.0	1.2	CH3	5.6	1.5
HCL	CH3	1.2	1.1	CH3	0.1	1.9	CH3	0.5	1.2	CH3	0.6	1.4
MOH	FP3	0	0.3	FP3	2.6	0.9	FP3	0	0.4	FP3	0.9	0.5
O-X	FP2	0	1.4	FP2	0	1.2	FP2	0	1.3	FP2	0	1.3
M-X	FP2	0	3.1	FP2	0	2.7	FP2	0	2.8	FP2	0	2.3
P-X	FP2	0	2.5	FP2	0	2.2	FP2	0	2.2	FP2	0	2.3

[A]Averages over spectral files with this run designation
[B]Average of 822R1c, 822R2c, and 822R3c results.

Table 13. Shakopee 8/02 Average Results by Run Designation

	802R1 (ppm)[A]			802R2 (ppm)[A]			802R3 (ppm)[A]			803 R4 (ppm)[A]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP3	3.6	1.0	FP3	2.0	0.8	FP3	0.5	0.7	FP3	0	0.8
TOL	CH4	3.9	3.3	CH4	3.8	3.3	CH4	4.2	3.3	CH4	4.1	3.4
HEX	CH5	8.7	0.4	CH5	9.1	0.5	CH5	8.4	0.4	CH5	8.4	0.4
H2CO	CH3	2.0	0.4	CH3	1.4	0.4	CH3	2.2	0.3	CH3	1.9	0.3
HCL	CH3	1.9	0.4	CH3	1.1	0.3	CH3	0.9	0.3	CH3	1.0	0.3
MOH	FP3	1.4	0.1	FP3	0.8	0.1	FP3	0.1	0.1	FP3	0	0.1
O-X	FP2	0	0.8	FP2	0.7	0	FP2	0	0.7	FP2	0	0.7
M-X	FP2	0	2.1	FP2	0	1.9	FP2	0	1.8	FP2	0	1.8
P-X	FP2	0	1.6	FP2	0	1.5	FP2	0	1.4	FP2	0	1.4

[A]Averages over spectral files with this run designation.

Table 14. Shakopee 8/02 Average Results

	802 AV (ppm)[A]		
Compound	region	conc.	2σ unc.
PHE	FP3	1.4	1.0
TOL	CH4	4.0	3.3
HEX	CH5	8.7	0.4
H2CO	CH3	1.9	0.3
HCL	CH3	1.2	0.3
MOH	FP3	0.6	0.2
O-X	FP2	0	0.7
M-X	FP2	0	1.9
P-X	FP2	0	1.5

[A]Average of 802R1, 802R2, 802R3, and 802R4 results.

Table 15. Shakopee 8/03 Results by Run Designation

	803R1 (ppm)[A]			803R2 (ppm)[A]			803R3 (ppm)[A]			803 AV (ppm)[B]		
Compound	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.	region	conc.	2σ unc.
PHE	FP1	12.8	1.1	FP1	11.4	1.0	FP1	12.8	1.1	FP1	12.3	1.1
TOL	FP2	0	1.3	FP2	0	1.2	FP2	0	1.2	FP2	0	1.2
HEX	CH5	73.0	3.8	CH5	58.4	3.0	CH5	76.5	4.3	CH5	69.3	3.7
H2CO	CH3	0	2.2	CH3	0	1.9	CH3	0	2.2	CH3	0	2.1
HCL	CH3	0.2	2.1	CH3	1.8	1.7	CH3	0.4	2.0	CH3	0.8	1.9
MOH	FP3	0.5	0.5	FP3	2.6	0.5	FP3	0	0.5	FP3	1.1	0.5
O-X	FP2	0	0.7	FP2	0	0.7	FP2	0	0.7	FP2	0	0.7
M-X	FP2	0	2.0	FP2	0	1.9	FP2	0	1.8	FP2	0	1.9
P-X	FP2	0	1.5	FP2	0	1.5	FP2	0	1.4	FP2	0	1.5

[A]Averages over spectral files with this run designation.
[B]Average of 803R1, 803R2, and 803R3 results.

ARMA MACT Analysis, Appendices

Appendix C.

"The Magnitude and Source of Air Emissions from Asphalt Blowing Operations", Environmental Progress, Spring 1998, David C. Trumbore.

Sampling results for Linnton 1994, and the HCl sampling for Medina (1995) and Minneapolis (1999).

The Magnitude and Source of Air Emissions from Asphalt Blowing Operations

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The US EPA has developed emission factors for estimating the emissions of filterable particulate, total organic compounds, and carbon monoxide from asphalt blowing operations. These are published by the EPA in a series called AP-42, which contain factors for many manufacturing processes. The emission factors for asphalt blowing are acknowledged by the EPA to be of poor quality. Owens Corning has taken extensive data in various manufacturing facilities and an asphalt Pilot Plant to provide more information on air emissions from these operations. The results of that work clearly show that the current AP-42 emission factors for asphalt processed by air blowing are deficient in that they omit significant emissions of SO_x and HCl, overestimate particulate and CO emissions, and potentially underestimate both VOC and NO_x emissions. In fact, SOx, which is not addressed by AP-42, is the major air emission contributed by the fumes from the asphalt blowing process when those fumes are incinerated. The sources of SO_x from air blowing are discussed in detail in this paper. The impact of incineration temperature on carbon monoxide is also illustrated. With the exception of HCl, the hazardous air pollutants encountered in the asphalt blowing process are minimal.

INTRODUCTION

The use of asphalt as a material is prevalent throughout recorded history. The commercial use of air blown asphalt, also known as oxidized asphalt, dates from the late 19th century [1]. Oxidized asphalt is produced by blowing air through hot petroleum residuum, which can come from vacuum distillation towers, atmospheric towers or solvent extraction units. At the start of the batch, input residuum is typically pumped through a direct fired non-contact preheater to achieve temperatures over 400°F (204°C), and into reaction vessels called oxidizers, or alternately, stills or convertors. Air is injected into the oxidizer and dispersed through perforated pipes. Air flow is typically in the range of 15 to 50 cfm/ton (0.008 to 0.026 m^3/sec/Mg) of asphalt and the oxidizer is typically operated between 400 and 550°F (between 204 and 288°C) [2]. Oxygen is consumed by the reaction of air with the petroleum residuum, resulting in fumes exiting the oxidizer at less than 10% oxygen content. Many theories exist as to the specific chemistry of the asphalt blowing reaction, with no consensus as to what is really happening. It is clear that in the asphalt blowing reaction oxygen functionality is added to the asphalt molecules; the apparent molecular weight of the asphalt increases; and compounds like hydrogen sulfide, methane, water, carbon monoxide, and carbon dioxide are released [3,4,5]. In addition to the gases formed, the high air flows both evaporate and entrain oily materials from the residuum, which can condense further down the process. These are referred to in this article as process oils. Fumes from asphalt blowing processes are typically treated with a variety of separation devices to remove condensing or entrained process oil, and then are incinerated. The most commonly used catalyst for the reaction is ferric chloride, although most oxidized asphalt is produced without any catalyst.

Air blowing of residuum results in an increase in Ring and Ball Softening Point (ASTM D36) and Brookfield Viscosity (ASTM D4402), and a decrease in Penetration (ASTM D5). The product is unique in that its combination of properties cannot be produced by any other refinery process. That is, if the softening point of the residuum is raised by distillation or solvent extraction the material is far more brittle than if the softening point is raised by air blowing. Oxidized asphalt is used for the manufacture of asphalt shingles; and in built-up roof construction, adhesives, corrosion protection, waterproofing, and a wide variety of specialty applications. The two highest volume products made using this process, shingle coating and BURA Type III asphalt, typically see a softening point increase during the blowing process from an initial value of less than 100°F (38°C) to a final value of 200°F (93°C) or higher.

Title V of the 1990 Clean Air Act required the accurate estimation of emissions from all U.S. manufacturing processes, and placed the burden of proof for that estimate on the process owner. In response to Title V, Owens Corning (OC) analyzed existing data and conducted extensive testing of their asphalt blowing processes in plant and pilot plant scale to develop the best possible emission factors. This paper is the result of that work, and it is our hope that it will lead to improved AP-42 emission factors for the asphalt blowing process.

Table 1. Test Methods Used in Sampling Air Blowing Emissions

EPA Method #	Items Measured Using Method
1	Sample and velocity traverses
2	Stack gas velocity & flow
3	Dry molecular weight
3A	Oxygen & Carbon dioxide
4	Stack moisture
5	Particulate
5A	Particulates
6C	Sulfur oxides
7E	Nitrogen oxides
10	Carbon Monoxide
25A	Total gaseous organic (VOCs)
26	Hydrogen chloride
26A	Hydrogen chloride
29	Inorganic compounds
202	Condensible particulate
0010	Semi-volatile HAPs

TEST METHODS

Testing of emissions from Owens Corning's asphalt blowing processes was done using the EPA test methods outlined in Table 1.

AP-42 Emission Factors

The Emission Factor and Inventory Group (EFIG) in the U. S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS) develops and maintains a database of emission factors for manufacturing processes. These emission factors are published in a series known as AP-42 [6]. As part of this process the emission factors have been assigned a quality rating. AP-42 emission factors for limited pollutants exist for the asphalt blowing process [7]. The factors are available for filterable particulates (PM), total organic compounds (VOC), and carbon monoxide (CO). They are summarized in Table 2. These emission factors have been assigned "D" or "E" ratings, indicating they are no better than "Engineering Judgment" in accuracy. More specifically a "D" rating indicates below average quality based on a small number of possibly non-random facilities with evidence of test variation. An "E" rating indicates poor quality based on unproved test methods, and issues with a low number of data points, randomness, and variability. An "E" rating is the lowest rating given to emission factors by AP-42 [6]. The asphalt blowing AP-42 factors are for both saturant and coating asphalt manufacture. The rest of this article only addresses the coating factors, which are larger in proportion to their longer processing times.

Owens Corning Plant Testing Results

The results of emission testing for Criteria Pollutants done on 33 different occasions in 14 different Owens Corning plant locations are shown in Table 3. The processes shared common process conditions: 15 to 30 cfm/ton (0.008 to 0.016 $m^3/sec/Mg$) air injection and 460 to 510°F (238 to 266°C) reaction temperature, common control equipment (fumes bubbled through a liquid seal in a knock out tank followed by gas fired incineration in an incineration chamber designed for adequate turbulence), and were processed to a common end point (coating asphalt). Widely variable input petroleum residuum were used in the tests. There was no catalyst used in any of the tests reported in Table 3. In all but one case, each data point is the average of three determinations, taken during three separate process times, with the same input residuum, under as similar as possible process conditions. The exception to that is the case of the PM data for plant J from 1984 to 1994. In this case an average of 83 different determinations were used to avoid skewing the overall PM data for only one plant configuration.

Averages and other statistics for each criteria pollutant are given at the bottom of Table 3. The arithmetic mean and median are included for each pollutant. The geometric mean is also included in Table 3, and could in some cases be appropriate because of the exponential nature of the dependence of the emissions data on some process conditions. As can be seen in Table 3, the arithmetic mean is the most conservative estimate and all further analyses in this paper use it as the most representative value of the data set. These data are the basis of what we believe to be improved emission factors for asphalt blowing, and in lieu of other available data, we recommend the arithmetic means be accepted as new emission factors for asphalt blowing with gas incineration. When used to estimate emissions, the emission factors are adjusted depending on the configuration and the amount of data existing for that particular plant. For example, the average value plus two or three standard deviations are often used to ensure that the estimate is greater than the actual emission.

CONTRIBUTION OF INCINERATION FUEL TO EMISSIONS

To apply the data of Table 3 to processes using fuel oil, rather than natural gas, for incineration requires that the contribution of the fuel burned be recognized. This is done by calculating the incremental emissions from the

Table 2. US EPA Emission Factors for Asphalt Blowing Emissions from AP-42 (7)

Pollutant	Method	Control Equipment	Saturant Asphalt	Coating Asphalt	Emission Factor Rating
Filterable PM	EPA 5A	none	6.6 lb/ton[1]	24 lb/ton	E
Filterable PM	EPA 5A	incineration	0.27 lb/ton	0.81 lb/ton	D
Total Organic Compounds	EPA 25A	none	1.3 lb/ton	3.4 lb/ton	E
Total Organic Compounds	EPA 25A	incineration	0.0043 lb/ton	0.017 lb/ton	D
Carbon Monoxide		none		0.27 lb/ton[2]	E
Carbon Monoxide		incineration		3.7 lb/ton[2]	E

[1] 1 lb/ton = 0.5 kg/Mg
[2] unclear what product was manufactured.

Table 3. Emission Factor Data for Asphalt Blowing to Coating with Gas Incineration

Plant	SOx (lb/ton)[1]	CO (lb/ton)	NOx (lb/ton)	VOC (lb/ton)	PM (lb/ton)	Comments	Year Tested
A	0.63	0.43	0.06	0.08		2 oxidizers	1996
A					0.02	2 oxidizers	1996
B		0.72		0.002	0.17		1996
C		0.07					1988
C	0.88	0.11	0.08	0.02	0.06		1994
C					0.08	Incinerator @ 1500F[1]	1992
D		0.95			0.07		1988
F					0.07		1990
F					0.07		1990
F					0.06		1990
H	0.84	0.09	0.02	0.01	0.18	2 oxidizers	1994
I					0.05		1993
I	0.66	0.002	0.08	0.10	0.14	Incinerator @ 1625F	1993
J					0.11	average of 83 PM tests	1984-1994
J		0.01			0.18	Incinerator @ 1550F	1992
J					0.02		1995
K					0.08		1986
L	0.86	0.34	0.10	0.002	0.12	Incinerator @ 1550F	1993
L	0.95	0.77	0.02	0.02	0.11	Incinerator @ 1550F	1994
L	0.65	0.33	0.05	0.001			1997
M					0.23		1992
M					0.25		1988
M	1.03	3.2	0.03	0.04		3 oxidizers	1994
M	0.76				0.03	2 oxidizers	1995
M					0.06	2 oxidizers	1996
M					0.07		1995
M		1.15				Incinerator @ 1400F	1995
M		0.17				Incinerator @ 1450F	1995
M		0.12				Incinerator @ 1500F	1995
N	0.95	0.01	0.02	0.07	0.04		1996
P					0.03	2 oxidizers	1984
P	0.93	0.21	0.12	0.002			1993
S	1.15	2.00	0.04	0.06		4 oxidizers	1993

Summary	SOx	CO	NOx	VOC	PM
Arithmetic Mean	0.86	0.59	0.05	0.03	0.10
Geometric Mean	0.84	0.18	0.04	0.01	0.08
Median	0.87	0.27	0.05	0.02	0.07
Std Dev	0.16	0.83	0.03	0.03	0.06
Arith. Mean+3s	1.34	3.09	0.16	0.14	0.29
Minimum	0.63	0.002	0.02	0.001	0.02
Maximum	1.15	3.20	0.12	0.10	0.25
Number	12	18	11	12	24

[1] 1 lb/ton = 0.5 kg/Mg, °C = (°F-32)*5/9

alternate fuel by using AP-42 emissions factors for combustion [8,9] and adding that source of emissions to the data in Table 3 for gas incineration. The incremental emissions subtract the gas combustion emissions from the fuel oil combustion emissions. Table 4 contains asphalt blowing emission factor data measured in four plants using heavy fuel oil. To illustrate the technique described above, the average of the measurements in these plants is compared to an average predicted by adjusting the gas incineration average from Table 3 with fuel oil emissions for a typical fuel oil usage rate.

Table 4. Evaluation of Emission Factors for Air Blowing Coating Asphalt with Heavy Fuel Oil Incineration

Plant	SO_x (lb/ton)[1]	CO (lb/ton)	NO_x (lb/ton)	VOC (lb/ton)	PM (lb/ton)	Year
F		0.31			0.03	1985
Q					0.28	1989
Q	1.38	0.02	0.12	0.01	0.30	1994
Q	1.14	0.00	0.19	0.01	0.35	1994
X	1.50	1.25	0.04	0.01	0.09	1993
P	2.87	0.37	0.15	0.00		1993
Average	1.72	0.39	0.13	0.01	0.21	

[1] 1lb/ton = 0.5 kg/Mg

Gas Data Averages from Table 3 Adjusted for Fuel Oil Emissions.

SO_x (lb/ton)1	CO (lb/ton)	NO_x (lb/ton)	VOC (lb/ton)	PM (lb/ton)
1.53	0.60	0.14	0.03	0.14

CRITERIA POLLUTANT SUMMARY

Table 5 summarizes the comparisons between current AP-42 emission factors for asphalt blowing, the data gathered by Owens Corning on 33 occasions in 14 plants using gas incineration, and estimated values for the contribution of the gas fuel that is burned in the incinerator.

The key conclusions from this comparison follow:

1.It is clear from the data in Table 5 that the omission of a sulfur oxide (SO_x) emission factor for the asphalt blowing process from AP-42 ignores what is usually the largest criteria pollutant from this process. The average value in all our testing is 0.86 lb SO_x/ton asphalt (0.43 kg/Mg) with gas fueled incinerators without using catalysts. This represents a significant source of SOx that should be accounted for in all asphalt blowing operations.

2.The AP-42 factor for carbon monoxide (CO) of 3.7 lb/ton (1.85 kg/Mg) is obviously based on poor incineration as it is excessively high for normal processes. In all of our testing on gas systems with adequate incineration turbulence and without any catalyst the average CO factor was 0.59 lb/ton (0.295 kg/Mg). Our one value close to AP-42, 3.2 lb/ton (1.6 kg/Mg) in plant M, was reduced to less than 0.2 lb/ton (0.1 kg/Mg) by raising the incineration temperature 100 °F (38°C). The sensitivity of CO to incineration temperature will be discussed below.

3.The AP-42 factor for volatile organic compounds (VOC) of 0.017 lb/ton (0.0085 kg/Mg) is achievable (5 out of 12 measurements we took were less than that value), but is approximately one half of the average measured value. This factor should be increased.

4. The AP-42 value for particulate material (PM) is much too high. Our largest reading in 24 tests was still less than 1/3 the AP-42 value and our average was 1/8 the AP-42 value.

5. The contribution of fuel burning to nitrogen oxide (NO_x) emissions gives an order of magnitude estimate of NO_x emissions in the asphalt blowing process. Some additive emissions appear to be warranted from the data, but this omission from the AP-42 factors is not a serious one.

6. Based on comparisons in Table 4, asphalt blowing emission factors based on gas incineration systems can be used as approximate estimates for systems using alternate fuels by adding the emission contribution of the alternate fuel calculated using AP-42 for combustion.

SOURCES OF SPECIFIC ASPHALT BLOWING EMISSIONS

Sulfur Oxides

SO_x emissions in the asphalt blowing process come from three sources:

1.The fuel used to incinerate the asphalt blowing fumes contains sulfur compounds which are oxidized on incineration to produce SOx emissions.

2. Some process oil is carried over as condensable vapor or droplets in the fume stream and, when burned, the sulfur, which exists primarily as thiophenes, is oxidized to produce SO_x emissions.

3. Hydrogen sulfide (H_2S) is formed in the asphalt blowing process and that material oxidizes in the fume stream and in the incinerator to produce SOx emissions.

The incineration fuel component is quite small when using natural gas, as shown in Table 5. Estimates of the magnitude of the other two components can be made from observations of results of experiments to reduce these emissions. The use of H_2S scavengers in the asphalt blowing process to tie up the H_2S component of the emission has been seen to give a maximum reduction in SO_x emissions of about 70 to 80% in a gas incineration situation [10]. This would indicate that the contribution of the release of H_2S in the process is about 70 to 80% of the emission in a gas incineration system. Similarly, unpublished work with filtration of pilot scale asphalt blowing fumes indicated that completely eliminating droplet carryover in an asphalt blowing process with gas incineration reduced SO_x emissions by 20 to 30%. Therefore, in a gas incineration system the contributions to SO_x emissions could reasonably be estimated as indicated in Table 6.

Table 5. Summary of Emission Factors for Asphalt Blowing Process Making Coating

	SO_x (lb/ton)[1]	CO (lb/ton)	NO_x (lb/ton)	VOC (lb/ton)	PM (lb/ton)
AP-42 Factor (Table 2)	omitted	3.7	omitted	0.017	0.81
Average OC Emission for Gas Incineration (Table 3)	0.86	0.59	0.05	0.03	0.10
Range of OC Values (Table 3)	0.63 to 1.15	0.002 to 3.2	0.02 to 0.12	0.001 to 0.10	0.02 to 0.25
Contribution from gas fuel estimated with AP-42 (8)	0.0002	0.007	0.03	0.002	0.004

[1] 1 lb/ton = 0.5 kg/Mg

Table 6. Sources of SO_x in Asphalt Blowing - Typical Values

Source of SO_x	Typical Contribution
Gas fuel for incinerator	< 0.1% of the total SO_x
H_2S release from Asphalt During Blowing	70 to 80% of the total SO_x
Carryover of process oil containing thiophene sulfur	20 to 30% of the total SO_x

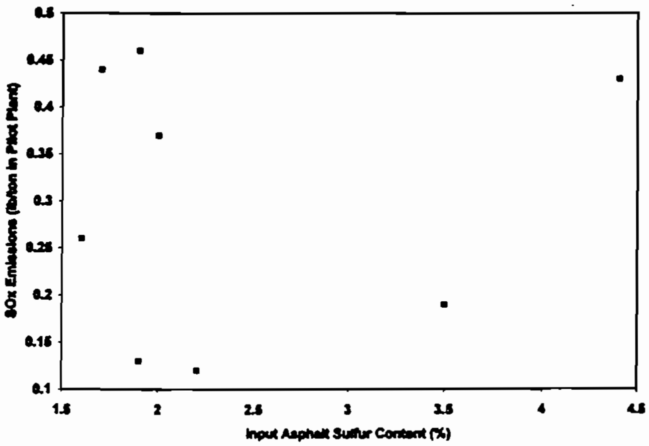

FIGURE 1. Correlation of input asphalt sulfur content With SO_x emissions. Eight different crude sources used in study. Correlation coefficient = 0.09 (1lb/ton = 0.5 kg/Mg).

Because of the strong contribution of some input petroleum residuum sulfur to SO_x, an investigation was done to determine if the total sulfur content of input residuum, which is easily measured, would correlate with SO_x emissions. To determine this a series of input residuum made with different crude oils were brought to Owens Corning's asphalt blowing pilot plant and oxidized under identical conditions, with determination of emission factors for SO_x. The results of these tests are shown in Figure 1, a plot of pilot plant SO_x emissions versus total sulfur content of the input asphalt. It is clear that no correlation exists, implying that only a small, unidentified, component of the sulfur in the asphalt is responsible for the H_2S release and subsequent SO_x emission.

Table 7. Effect of Incineration Temperature on Carbon Monoxide Emissions

Plant	CO Emission Factor (lb/ton)[1]	Incineration Temperature (°F)[1]
M	1.15	1400
M	0.17	1450
M	0.12	1500
L[2]	2.15	1450
L	0.17	1550

[1] 1 lb/ton = 0.5 kg/Mg, °C = (°F-32)*5/9

[2] The L plant data was taken with ferric chloride as a catalyst and is therefore not included in the Table 1 data set.

Carbon Monoxide

Large amounts of carbon monoxide can be emitted from the asphalt blowing process when the incineration conditions are less than optimum in terms of residence time, incineration temperature and fume turbulence. In Table 7 the effect of incineration temperature is shown for two asphalt blowing processes where the incineration residence time and turbulence are acceptable. As can be seen, the emission of carbon monoxide is very sensitive to a relatively small change in temperature. In general, we have found that for incinerators with more than 0.5 seconds of residence time and chambers designed to promote turbulence, incineration temperatures in the 1450 to 1550°F (788 to 843°C) range are necessary to achieve very low CO levels. From the data in Table 7, plant M needs to run at least 1450°F (788°C) while plant L needs to run 1550°F (843°C) to achieve emission factors under 0.2 lb/ton (0.1 kg/Mg).

A small amount of CO is detectable in the fumes prior to the incinerator, but the major source for CO emissions is incomplete combustion of hydrocarbons to carbon dioxide (CO_2).

Hydrocarbon Emissions – Particulate and VOCs

From the description of the asphalt blowing process, it is not surprising that the fumes entering the incinerator contain significant amounts of hydrocarbons. The reactions that occur in the process create lower molecular weight hydrocarbons that remain as vapor or condense at some point in the fume system. The incineration process does a good job of combusting these

Table 8. Measured Incineration Destruction Efficiencies for Hydrocarbons in the Air Blowing Process

Plant	# Samples Averaged	Residence Time (seconds)	Incineration Temperature (°F)[1]	Destruction Efficiency
C	3	1.8	1500	98.9%
S	4	1.9	1500	98.1%
S	4	1	1500	97.9%
S	5	0.7	1500	98.7%
S	4	0.5	1500	99.2%

[1] °C = (°F-32)*5/9

Table 9. Sampling Data for HAPs Emissions from Asphalt Blowing (1 lb/ton = 0.5 kg/Mg).

Plant	C	O	P	L	L	Q	Q	M	M
Year	1992	1990	1984	1994	1994	1994	1994	1995	1995
Fuel	gas	gas	gas	gas	gas	BD Oil	#5 Fuel	gas	gas
Comments				Ferric	No Ferric			Ferric	No Ferric
Hazardous Air Pollutant	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)	(lb/ton)
Hydrogen chloride			8.2E-03	2.5E-01	3.6E-02	8.4E-03	7.7E-03	1.9E-01	4.0E-02
<u>General Inorganic HAPS</u>									
Antimony				1.0E-06	7.7E-07				
Arsenic		0.0E+00		8.5E-07	2.8E-06	6.3E-07	6.3E-07		
Beryllium				8.5E-09	6.2E-09				
Cadmium		0.0E+00		5.7E-07	6.2E-09				
Chromium				3.2E-05	4.3E-06	4.1E-06	7.3E-06		
Cobalt						7.4E-07	8.9E-06		
Lead				3.2E-06	2.2E-06	1.3E-05	4.7E-05		
Manganese				5.5E-06	4.1E-06	9.9E-05	2.4E-04		
Nickel		4.2E-05		2.8E-04	6.3E-06				
Phosphorus				4.1E-06	2.2E-06				
Selenium		0.0E+00		8.1E-07	2.5E-06	6.3E-07	6.3E-07		
<u>General Organic HAPs</u>									
Benzene	2.6E-04	1.3E-02		8.2E-04	1.5E-03	9.0E-04	1.2E-05		
Toluene				1.3E-04	8.8E-05	3.4E-04	1.2E-05		
Ethyl Benzene						1.0E-02	1.2E-02		
Xylene						1.7E-04	9.0E-06		
111 TCE						2.1E-05	2.2E-05		
methyl chloride				2.1E-04	7.9E-04				
vinyl chloride				8.7E-05	9.7E-05				
ethyl chloride				5.5E-05	7.7E-05				
methylene chloride				1.3E-03	1.3E-03				
chloroform				1.0E-04	1.2E-04				
Di-n-butylphthalate				2.5E-06	3.0E-06				
Dibenzofuran				3.8E-05	6.1E-06				
bis(2-ethylhexyl)phthalate				9.6E-06	8.4E-06				
isophorone				3.0E-06	2.5E-06				
4-nitrophenol				1.6E-05	1.1E-05				
phenol				1.4E-05	7.4E-06				
o-cresol				2.4E-06	2.5E-06				
p-cresol				8.7E-06	5.7E-06				
<u>Polycyclic Organic Matter</u>									
2-methylnaphthalene				2.1E-05	4.7E-06	4.6E-08	8.2E-08		
Acenaphthene (ACEP)	0.0E+00			3.6E-05	2.5E-06	2.7E-07	8.4E-08		
Acencphthylene (ACEY)	6.7E-09					2.5E-08	6.7E-09		
Anthracene (ANTH)	0.0E+00					2.5E-09	5.6E-08		
Benz (A) anthracene (BENA)	0.0E+00					8.0E-09	6.2E-09		
Benzo (B) Fluoranthene (BENB)	0.0E+00					7.1E-09	7.9E-09		
Benzo(G,H,I) Preylene (BENG)	0.0E+00								
Benzo (K) Floouranthene (BENK)	0.0E+00								
Benzo (A) Pyrene (BEZA)	0.0E+00								
Benzo(e)pyrene						2.0E-08	2.2E-08		
Chrysene (CHRY)	0.0E+00					1.0E-08	1.4E-08		
Dibenz (A,H) Anthracene (DIBN)	0.0E+00								
Fluoranthene (FLUO)	0.0E+00			1.3E-05	2.5E-06	6.5E-09	2.0E-08		
Indeno (1,2,3-C,D) Pyrene (INDE)	0.0E+00								
Naphthalene (NAPH)	5.9E-06			5.3E-05	2.5E-05	8.9E-07	9.9E-07		
Phenathrene (PHEA)	0.0E+00			8.0E-05	6.9E-06	6.4E-08	6.4E-07		
Pyrene (PYRE)	0.0E+00			7.3E-06	2.5E-06	7.8E-09	1.8E-08		

to CO and CO_2 as indicated by the data in Table 8, which was taken by measuring total hydrocarbons entering the incinerator and total leaving to get a destruction efficiency. Because of the nature of the process there is an insignificant amount of inorganic components in the particulate emissions.

HAZARDOUS AIR POLLUTANTS TEST RESULTS

In addition to testing on criteria pollutants, Owens Corning has done extensive testing on the emissions of hazardous air pollutants (HAPs) from the asphalt blowing process. This testing, done in six plants on nine occasions, is summarized in Table 9. On different occasions four basic classes of HAPs have been measured: 1. hydrogen chloride, 2. general inorganic HAPs, 3. general organic HAPs, and 4. polycyclic organic matter (POM). Table 9 is organized around those groupings.

The data show that the use of ferric chloride as a catalyst significantly increases hydrogen chloride emissions from the 0.007 to 0.04 lb/ton (0.0035 to 0.02 kg/Mg) emission factor level without ferric chloride use to 0.19 to 0.25 lb/ton (0.095 to 0.125 kg/Mg) with the catalyst. This is an important omission from AP-42 and should be added for ferric chloride catalyzed asphalt blowing. The source of this chloride is free HCl in the ferric solution and the reaction of ferric chloride to ferrous chloride as part of the mechanism of catalysis [11]. Only a fraction of the HCl available from these two sources is actually evolved. The rest takes part in as yet unidentified reactions in the asphalt.

Emissions of general inorganic materials can be seen to be very small, in the range of 0.000000006 to 0.0002 lb/ton (0.000000003 to 0.0001 kg/Mg).

Emissions of general organic materials were very low with the exception of ethyl benzene and one measurement of benzene, which were in the range of 0.01 to 0.013 lb/ton (0.005 to 0.0065 kg/Mg). Clearly more severe incineration conditions can reduce these values, and this is indicated in other measurements of benzene emissions which were as low as 0.000012 lb/ton (0.000006 kg/Mg).

Emissions of POM were all extremely low ranging in measurement from 0.000000005 to 0.00008 lb/ton (0.0000000025 to 0.00004 kg/Mg).

CONCLUSIONS

From the data presented in this paper the following conclusions have been reached:

1. Current AP-42 emission factors for asphalt blowing ignore important emissions of sulfur oxides. This is usually the largest emission from the process. The emission of sulfur oxides are not correlated with total sulfur in the input residuum. In a gas incineration system the source of sulfur oxides are approximately 70 to 80% from H_2S released in the asphalt blowing reaction, 20 to 30% from entrained or condensing oils, and almost no contribution from the fuel used for incineration.

2. Current AP-42 emission factors for asphalt blowing ignore hydrogen chloride emissions, which are important when ferric chloride is used as a catalyst in the process.

3. Current AP-42 emission factors for asphalt blowing overestimate the emissions of particulate and carbon monoxide in a well designed process. Carbon monoxide emissions can be dramatically reduced with small increases in incineration temperature above a certain threshold temperature, in an incinerator with adequate residence time and turbulence. In our experience that threshold temperature is approximately 1400 to 1500 °F (760 to 816 °C).

4. Emissions of hazardous air pollutants, other than hydrogen chloride, from the asphalt blowing process are insignificant.

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ARMA MACT Analysis, Appendices

Appendix D.

Air Tech Report

Containing new data collected in April 2000 from Oxford, NC data for phenol and toluene.

AIR / TECH

Air-Tech Environmental, LLC

Telephone: (919) 544-6338
Fax: (919) 572-2203
E-Mail: answers@ipass.net

May 23, 2000

Steven J. Eckard, P.E.
Enthalpy Analytical, Inc.
3211 Bramer Drive
Raleigh, N.C. 27604

Amended

Dear Steve:

This letter report summarizes the testing performed by *Air-Tech Environmental* at the CertainTeed facility in Oxford, NC on April 25, 2000. Testing was performed to determine the levels of phenol and toluene present in the stack gas emissions at the HEAF outlet. All sampling activities were audited on-site by Mr. Walt Smith.

On April 25, three one-hour isokinetic samples were collected following the protocol of the draft EPA method entitled "Sampling and Analysis of High Levels of Phenol and Cresol Emissions From Stationary Sources" utilizing a Method 5 sampling train with 2 N sodium hydroxide as the absorbing solution (in place of water) along with a glass fiber filter. Samples were collected from three ports, with four traverse points per port. Pre- and post test leak checks were performed according to the method, all of which were acceptable. The sampling rates for the three test runs were within 10% of 100% isokinetic criteria.

In addition, three one hour samples using SKC charcoal tubes were collected for the determination of toluene emissions following the sorbent tube protocol of EPA Method 18. These were single point, non-isokinetic samples. Two sampling trains were operated simultaneously, one using a tube spiked with a known amount of toluene and the other using an un-spiked tube. The spiked tubes were supplied by Enthalpy Analytical. Each train used two tubes in series, a primary and a secondary back-up. The second tube for the spiked train was not spiked. All pre- and post-test leak checks were acceptable.

All recovered samples and reagent blanks were given to Enthalpy Analytical for analysis. The sample volumes, corrected to standard conditions of 68 degrees F and one atmosphere are provided in Table 1 below. Using the analytical results provided by Enthalpy Analytical, stack gas concentrations and emission rates were calculated and are presented in Table 2. Copies of all field data sheets are attached.

Post-it® Fax Note 7671	Date 08/11/00 # of pages ▶ 2
To Angela Jankowsky	From Russ Snyder
Co./Dept. EME	Co. ARMA
Phone # 303/279-7647	Phone # 301/348-2016
Fax # 303/279-8795	Fax #

Mailing Address: P. O. Box 12353
Shipping Address: 3714 S. Alston Avenue • Durham, North Carolina 27713-1804

Table 1. Sample Volumes

Run Number	*Phenol dscf*	*Toluene, Spiked dscf*	*Toluene, un-Spiked dscf*
1	49.7	1.76	2.01
2	50.8	2.27	1.78
3	50.8	1.62	1.88

Table 2. Stack Gas Concentrations and Emission Rates

Run Number	*Stack Flow dscfm*	*Phenol*		*Toulene*	
		ppm	*lb/hr*	*ppm*	*lb/hr*
1	11,843	< 0.08	< 0.013	0.42	0.071
2	11,786	< 0.08	< 0.013	0.26	0.045
3	11,842	< 0.07	< 0.012	0.26	0.044
Average	11,824	< 0.07	< 0.013	0.31	0.053

If you have any questions, you may call me at 544-6338.

Sincerely,

James F. McGaughey
Senior Staff Scientist

JFM/gtw

Attachments

Line #	Control Device in 1995	Years operating	Type of Line
1	Afterburner	Intermittently	1 shingle line
2	Afterburner	1980 - present	FG Shingles or rolls
3	Afterburner		Organic
4	Afterburner		Organic
5	Afterburner		Organic
6	Afterburner	1980	Roofing
7	Afterburner		Saturated Felt Line
8	Afterburner		Saturated Felt Line
9	Filtration		#1
10	Filtration		#1
11	Filtration		#2
12	Filtration		#2
13	Filtration		1 residential shingle line.
14	Filtration		1 shingle line
15	Filtration		1 shingle line
16	Filtration		1 shingle/roll line
17	Filtration		BUR
18	Filtration		FG felt roll roofing
19	Filtration		FG Shingle Line
20	Filtration		FG Shingles
21	Filtration		FG Shingles or rolls
22	Filtration		FG Shingles or rolls
23	Filtration		FG Shingles or rolls
24	Filtration		FG Shingles or rolls
25	Filtration		FG Shingles or rolls
26	Filtration		FG Shingles or rolls
27	Filtration		Fiberglass Felt Roll Roofing
28	Filtration		Fiberglass Felt Roll Roofing
29	Filtration		Fiberglass Felt Roll Roofing
30	Filtration		Fiberglass Felt Roll Roofing
31	Filtration		Fiberglass Shinges
32	Filtration		Mod Bit
33	Filtration		Mod Bit
34	Filtration		Mod Bit
35	Filtration		Mod bit

36	Filtration	Mod bit
37	Filtration	Mod Bit
38	Filtration	mod bit
39	Filtration	Mod Bit
40	Filtration	multiproduct line
41	Filtration	multiproduct line
42	Filtration	No 1 line
43	Filtration	No 2 (roll line)
44	Filtration	No 2 line
45	Filtration	Organic Felt Roll Roofing
46	Filtration	Roofing
47	Filtration	Saturated Felt Line
48	Filtration	smooth surfaced rolls
49	Mist Eliminator	#3234
50	Mist Eliminator	1 residential shingle line.
51	Mist Eliminator	1 shingle line
52	Mist Eliminator	AWA Line
53	Mist Eliminator	BUR
54	Mist Eliminator	COA-101
55	Mist Eliminator	Coated Roll Line
56	Mist Eliminator	Felt Saturator Line
57	Mist Eliminator	Felt Saturator Line
58	Mist Eliminator	FG felt roll roofing
59	Mist Eliminator	FG Shingles or rolls
60	Mist Eliminator	FG Shingles or rolls
61	Mist Eliminator	I shingle line
62	Mist Eliminator	IMP-501
63	Mist Eliminator	IMP-502
64	Mist Eliminator	L-3
65	Mist Eliminator	Mod Bit
66	Mist Eliminator	Mod bit/commercial rolls
67	Mist Eliminator	multiproduct line
68	Mist Eliminator	multiproduct line
69	Mist Eliminator	Organic Roofing
70	Mist Eliminator	Roofing
71	Mist Eliminator	Roofing
72	Mist Eliminator	Roofing

73	Mist Eliminator	Roofing
74	None	1 residential shingle line.
75	None	BUR
76	None	Coater
77	None	Felt Saturator Line
78	None	FG Shingles or rolls
79	None	FG Shingles or rolls
80	None	FG Shingles or rolls
81	None	FG Shingles or rolls
82	None	FG Shingles or rolls
83	None	FG Shingles or rolls
84	None	FG Shingles or rolls
85	None	I residential shingle line
86	None	Mod bit
87	None	Mod Bit
88	None	Mod Bit
89	None	Mod bit
90	None	Mod bit
91	None	Mod bit
92	None	P-100
93	None	RL-3
94	None	Saturated Felt Line
95	not incineration	Organi
96	not incineration	Organic
97	PM Control	Line 1 shingle line
98	PM Control	Line 2 shingle line
99	PM Control	mod bit
100	PM Control	No 1 line (shingle line)
101	Scrubbing	#1
102	Scrubbing	#2
103	Scrubbing	CTR-1
104	Scrubbing	CTR-3
105	Scrubbing	Felt Rolls
106	Scrubbing	FG Shingles
107	Scrubbing	Laminated Shingles, Coated Rolls
108	Scrubbing	Mod bit
109	Scrubbing	Mod bit

110	Scrubbing		Roofing
111	Scrubbing		Roofing
112	Scrubbing		Roofing
113	Scrubbing		Roofing
114	Scrubbing		Roofing
115	Scrubbing		Shingles
116	Thermal Oxidation	1980 - present	1 residential shingle line.
117	Thermal Oxidation	1989 - present	commercial roofing 1
118	Thermal Oxidation	1989 - present	commercial roofing 2
119	Thermal Oxidation	1992 - present	FG Shingles or rolls
120	Thermal Oxidation	1995 - present	Roofing
121	Thermal Oxidation	1992 - present	Roofing Line 1
122	Thermal Oxidation	1992 - present	Roofing Line 2
123	Unknown		BUR No Data
124	Unknown		Mod bit
125	Unknown		Mod bit
126	Unknown		Mod bit
127	Unknown		Roofing
128	Unknown		Roofing
129	Unknown		Roofing
130	Unknown		Roofing
131	Unknown		Roofing
132	Unknown		Roofing
133	Unknown		Roofing
134	Unknown		Roofing
135	Unknown		Saturated Felt Line
136	Unknown		Saturated Felt Line
137	Unknown		Unknown
138	Unknown		Unknown
139	Unknown		Unknown
140	Unknown		Unknown
141	Unknown		Unknown
142	Unknown		Unknown

Appendix F Table 3.1 of the Afterburner Systems Study

Table 3-1. THERMAL-AFTERBURNERS

Conditions Required for Satisfactory Performance
in Various Abatement Applications

Abatement Category	Afterburner Residence Time (Sec)	Temperature (°F)
Hydrocarbon Emissions (90% + Destruction of HC)	0.3-0.5	1100-1250[a]
Hydrocarbons + CO (90% + Destruction of HC + CO, as in LAAPCD Rule 66)	0.3-0.5	1250-1500
Odor		
(50-90% Destruction)	0.3-0.5	1000-1200
(90-99% Destruction)	0.3-0.5	1100-1300
(99% + Destruction)	0.3-0.5	1200-1500
Smokes and Plumes		
White Smoke (Liquid Mist)		
(Plume Abatement)	0.3-0.5	800-1000[b]
(90% + Destruction of HC + CO)	0.3-0.5	1250-1500
Black Smoke (Soot and Combustible Particulates)	0.7-1.0	1400-2000

a) Temperatures of 1400-1500°F may be required if the hydrocarbon has a significant content of any of the following: methane, cellosolve, substituted aromatics (e.g. toluene, xylenes).

b) Operation for plume abatement only is not recommended, since this merely converts a visible hydrocarbon emission to an invisible one, and frequently creates a new odor problem due to partial oxidation in the afterburner.